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PERFORMANCE OF A RESIDENTIAL HEAT PUMP OPERATING IN THE COOLING MODE WITH SINGLE FAULTS IMPOSED

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BRIEF SUMMARY OF THE RESEARCH

System behavior of a R410A residential unitary split heat pump system was investigated. The system was operated in cooling mode and used a thermostatic expansion valve (TXV) as the refrigerant expansion device. Seven artificial faults were tested: compressor/reversing valve leakage, improper outdoor air flow, improper indoor air flow, liquid line restriction, refrigerant undercharge, refrigerant overcharge, and presence of non-condensable gas in the refrigerant.

The no-fault test results were correlated to produce a reference model of 2^{nd} order multivariate regressive polynomials. The reference model used three independent variables, outdoor air temperature, indoor air temperature, and indoor dew point temperature, to correlate all other heat pump features. Standard deviations of liquid line refrigerant subcooling and evaporator exit refrigerant superheat were used as the main indicators for a steady-state detector algorithm. From the no-fault reference model, heat pump feature residuals were derived. Since the system was controlled by a TXV, the system could adapt itself to considerable external variation. Thus faulty behavior was not as detectable as it would have been with an orifice expansion device equipped system. The distinctiveness of a fault depended on the TXV status. Heat exchanger faults' effects upon performance depend on the sizing of the heat exchanger. From the dynamic tests, the system showed that the most influential factor for dynamic behavior was the change of the evaporator refrigerant exit temperature.

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NOMENCLATURE

Symbols

a	coefficient of multivariate polynomial
COP	Coefficient of Performance (–)
EER	Energy Efficiency Ratio (Btu/ (W h))
h	specific enthalpy, kJ/kg (Btu/lbm)
k	specific instant of kth time interval
m_{R}	refrigerant mass flow rate, kg/h (lbm/h)
m	average
n	number of data samples in a moving window
P	pressure, kPa (psia)
$P_{\mathrm{TXV,up}}$	upstream pressure of TXV, kPa (psia)
ΔP_{CR}	condenser refrigerant side pressure drop, Pa (psid)
ΔP_{ER}	evaporator refrigerant side pressure drop, Pa (psid)
ΔP_{LL}	liquid line pressure drop, Pa (psid)
Q	capacity, W (Btu/h)
Q_{CA}	condenser air-side capacity, W (Btu/h)
Q_{CR}	condenser refrigerant-side capacity, W (Btu/h)
Q_{EA}	evaporator air-side capacity, W (Btu/h)
Q_{ER}	evaporator refrigerant-side capacity, W (Btu/h)
$Q_{\mathrm{EA,lat}}$	indoor air latent capacity, W (Btu/h)
$Q_{\mathrm{EA,sens}}$	indoor air sensible capacity, W (Btu/h)
R	residual of features
R^*	normalized residual
SCFM	air side flow rate (ft^3/min, scfm)
SEER	Seasonal Energy Efficiency Ratio (Btu/(W h))
SHR	Sensible Heat Ratio (–)
T	temperature, °C (°F)
T_{CR}	condenser inlet saturation temperature, °C (°F)
T_{DW}	compressor discharge-line wall temperature, °C (°F)
T_{EAID}	evaporator air inlet dewpoint temperature, °C (°F)
T_{EAOD}	evaporator air exit dewpoint temperature, °C (°F)
T_{ER}	evaporator exit saturation temperature, °C (°F)
T_{ID}	indoor dry-bulb temperature, °C (°F)
T_{IDP}	indoor dew-point temperature, °C (°F)
T_{OD}	outdoor dry-bulb temperature, °C (°F)
T_{SW}	compressor suction-line wall temperature, °C (°F)
ΔT_{CA}	condenser air temperature rise, °C (°F)
ΔT_{EA}	evaporator air temperature drop, °C (°F)
ΔT_{LL}	liquid line temperature drop, °C (°F)
ΔT_{sc}	liquid line subcooling, °C (°F)
ΔT_{sh}	evaporator exit superheat, °C (°F)
v	variance
W_{cmp}	compressor work (W)
x	measured data
$\bar{x}$	moving window average of measured data

Greek symbols

ϕ	feature or performance parameter
ϕ_{EAI}	evaporator air inlet relative humidity (–)
ϕ_{EAO}	evaporator air exit relative humidity (–)
σ	standard deviation

Subscripts

avg	average
cmp	compressor
CA	outdoor air
CAI	outdoor air condenser inlet
CAO	outdoor air condenser exit
CR	condenser refrigerant
CRI	condenser refrigerant inlet
CRO	condenser refrigerant exit
EA	indoor air
EAI	indoor air evaporator inlet
EAO	indoor air evaporator exit
ER	evaporator refrigerant
ERI	evaporator refrigerant inlet
ERO	evaporator refrigerant exit
DB	dry bulb
DP	dew point
ID	indoor chamber
OD	outdoor chamber
RH	relative humidity
sat	saturation

Abbreviations

AC	air conditioner
CF	condenser fouling (improper outdoor air flow)
CMF	compressor valve or 4-way reverse valve leakage fault
DOE	U.S. Department of Energy
EF	evaporator fouling (improper indoor air flow)
EPA	U.S. Environmental Protection Agency
FDD	fault detection and diagnosis
HP	heat pump
HVAC	heating, ventilating and air-conditioning
IC	improper charge of refrigerant
LL	liquid line restriction fault
NON	presence of non-condensable gas fault
OC	refrigerant overcharge
RH	relative humidity
UC	refrigerant undercharge
TXV	thermostatic expansion valve

CHAPTER 1. RATIONALE FOR THE STUDY

An increasing emphasis on energy saving and environmental conservation requires that air conditioners and heat pumps be highly efficient. To this end, several government initiatives have been undertaken. For example, the U.S. Environmental Protection Agency (EPA)'s Global Programs Division is responsible for the assessment of alternative refrigerant performance and enforcement of the Clean Air Act. Another prime example is the ENERGY STAR initiative, a program formulated by the EPA/Climate Protection Partnerships Division and the Department of Energy (DOE), which promotes products that offer energy efficiency gains and pollution reduction. Directly affecting residential equipment, a recent DOE regulation imposes a 30 % increase in the minimum seasonal energy efficiency ratio (SEER) for central air conditioners, from 10.0 to 13.0, beginning January 23, 2006 (Federal Register, 2001).

To assure that heating, ventilating, air-conditioning (HVAC) equipment operates in the field at its design efficiency, the efforts exerted by equipment manufacturers to improve equipment SEER must be paralleled in the field by good equipment installation and maintenance practices. However, a survey of over 55000 residential and commercial units found the refrigerant charge to be incorrect in more than 60 % of the systems (Proctor, 2004). Another independent survey of 1500 rooftop units showed that the average efficiency was only 80 % of the expected value, primarily due to improper refrigerant charge (Rossi, 2004). A low refrigerant charge in the system may be due to a refrigerant leak or improper charging during system installation. While the most common concern about a refrigerant leak is that a greenhouse gas has been released to the atmosphere, a greater impact is caused by the additional CO_2 emissions from fossil fuel power plants due to the lowered efficiency of the air-conditioning (AC) unit.

Proctor's survey shows a correlation between the quality of installation and technician training and supervision. Proper training of the technician is a necessary requirement for proper installation. But the survey also showed clearly that the number of return calls to correct improper installation was lowest when routine oversight of the installation work was provided, and that the number of faulty installations markedly increased when post-installation inspection visits were eliminated. At present, the homeowner has no quality assurance method for equipment installation as long as his/her comfort is not compromised.

The goal of this project is to study and develop fault detection and diagnostic (FDD) methods which would provide a technician with a fault diagnosis and could alert a homeowner when performance of their AC unit falls below the expected range, either during commissioning or post-commissioning operation. For the homeowner, this FDD capability could be incorporated into a future smart thermostat where a readout on performance would allow basic oversight of the service done on the unit and register the effects of that service upon performance.

The benefits of FDD methods for ACs and HPs are numerous and they include;

- reduction of energy use
- reduction in peak demand of electricity
- reduction in CO_2 emissions from fossil fuel power plants
- reduction in refrigerant emissions from AC and HP systems
- reduction in down time and maintenance cost
- improvement of thermal comfort

Arguably, development of FDD methods for split equipment presents unique challenges because these systems are assembled on site. Varied assembly skill levels and lack of attention to manufacturer recommendations is the prime reason that automated FDD methods be developed. FDD will provide "Automated Oversight" of servicing and warning of refrigerant charge loss, which is the most frequent problem in field assembled systems. It should be noted that the refrigerant leak problem may become even more frequent with the industry transition from medium pressure R22 to higher pressure R410A.

Fault detection and diagnosis is accomplished by comparing a system's current performance or parameters with those expected based on the measurements taken from the system when it was known to operate fault-free. Consequently, FDD method development includes a laboratory phase during which fault-free and faulty operations are mapped. The faults are artificially imposed to learn about the system's response to them. The analytical phase, which follows, is concerned with using the obtained database to develop methods for fault detection and diagnosis. This report documents the laboratory phase of the FDD study carried out on a residential heat pump operating in the cooling mode.

Fault detection and diagnosis has been effectively applied for some time in critical systems and processes, e.g., aerospace and nuclear industry applications, and in chemical processes. FDD methods for HVAC&R systems have been under development since the late 1980's (McKellar, 1987; Pape et al., 1991; Grimmelius et al., 1995; Stylianou and Nikanpour, 1996). The majority of the early research was devoted to variable air volume air-handling units. On the vapor-compression side, most work was devoted to large systems, particularly to water chillers and single-package air conditioners (Rossi and Braun, 1997; Castro, 2002; Li and Braun, 2003), while split air-conditioning and commercial refrigeration systems received little attention.

CHAPTER 2. LITERATURE REVIEW

2.1 Research Background

Due to explosively growing energy needs and the global warming problem, energy conservation has become a top priority. For the heating, ventilating, air-conditioning, and refrigerating (HVAC&R) industry, research has been concentrating on the development of new air-conditioning technologies and improving the energy efficiency of existing vapor compression system designs.

FDD systems were originally developed for the purpose of safety for nuclear power plants or aircraft (Braun, 1999). In such applications, FDD systems are equipped for fail-safe operation disregarding cost. On the other hand, a number of recent industrial applications pursue the reduction of total costs related to equipment downtime, service costs, and utility costs. FDD systems may be applied to reduce costs associated with all of these concerns.

As a result of the decreasing price of sensors and microprocessors, developers can affordably apply FDD systems to automatic management of even non-critical HVAC&R systems. In addition, remote management systems are being developed using information-based network approaches to increase energy efficiency (Snoonian, 2003). A number of recent research efforts for optimized management systems are being carried out in order to reduce energy consumption (Brownell et al., 1999; Seem et al., 1999; Hayter et al., 1999; Breuker et al., 2000; Roth et al., 2005)

Generally, optimized management systems require the monitored equipment to perform their regular operation without any failure or fault. It is quite possible that the management system may not perform as desired due to internal faults. For difficult cases, some faults that have been neglected or considered as negligible may reveal a fatal problem that requires a costly repair. Therefore, to protect the system from catastrophic failure or performance degradation caused by various faults, it is desirable to introduce the concept of fault detection and diagnostic (FDD) systems to this equipment. To do this, the real time behaviors of residential air-conditioning units should be continuously monitored. Recently, research interests have focused on environmentally-benign household configurations, which encompass the FDD system as an active part of an automated building management system (Wang et al., 2000; Wu and Wang, 2002).

The energy savings attributable to FDD depends on the frequency and severity of faults. A brief note based on interviews with practicing engineers and contractors reported that inefficient operation wastes at least 20 % to 30 % of the entire HVAC energy consumption (Westphalen et al., 2003). For rooftop air-conditioning units, the average efficiency was estimated at 80 % of the expected value. Approximately 50 % of installations were reported to have efficiency of 80 % or less and 20 % of installations had efficiency of 70 % or less (Rossi, 2004).

Proctor (2004) surveyed over 55,000 commercial and residential air-conditioning units in California. Proctor reported that residential systems are better managed than commercial systems; however, their overall quality control was poor. From the report, 95 % of residential units failed the diagnostic test. The main reasons causing the failures are listed as duct leakage, poor insulation, resistance to air flow, improper refrigerant charge, low evaporator air flow, over-sized units, or non-condensables in the refrigerant. Furthermore, the refrigerant charge in residential air-conditioning units was incorrect 62 % of the time, and charge in commercial units was incorrect 60 % of the time. Proctor also provided other survey results concerning improper installation and management problems. Proctor's survey shows a correlation between the quality of installation and the technician's training and supervision.

Figure 2.1 represents national energy flow for the United States in 2004 (DOE/EIA-0384, 2005). Numbers by sectors represent units of energy in quads (1 quad = 1 quadrillion BTU = 1×10^{15} BTU = 1.055×10^{15} kJ). Although residential and commercial energy demand occupies approximately 40 % of national energy demand, it has received less attention than industrial demand. Considering that some small commercial users utilize residential HVAC systems, energy savings efforts should be increased for residential HVAC systems. Proper commissioning of HVAC equipment could typically reduce annual energy consumption by 5 % to 30 % depending on the building type (Roth et al., 2003). It could reduce commercial building HVAC energy consumption by about 0.5 quads. Based upon national energy consumption of approximately 100 quads annually, Figure 2.1, the total savings can be estimated at 1 % to 2 % including residential and commercial demands.

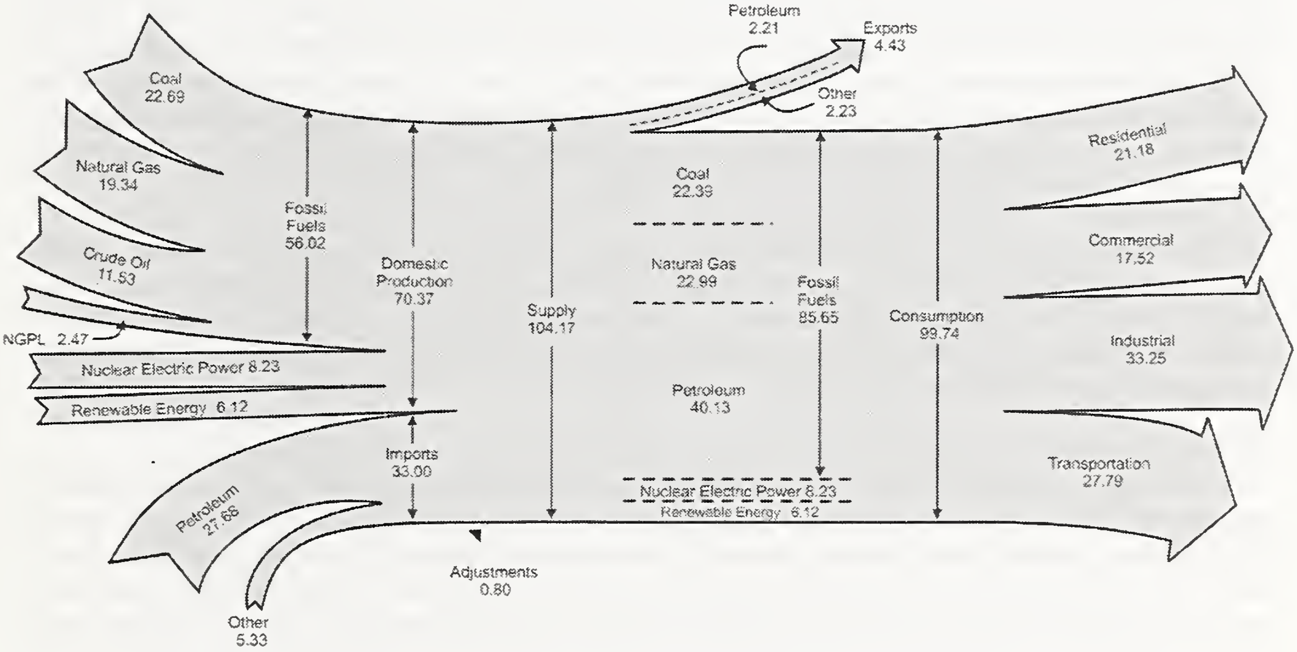


Figure 2.1. Energy flow of the United States in 2004. Units in quadrillion BTU (DOE/EIA-0384, 2005)

2.2 Previous Research

Initial FDD research in the HVAC&R field was performed for variable air volume air-handling units and chillers. During the development of the first FDD techniques, energy savings was a secondary consideration to preventing equipment malfunction. Anderson et al. (1989) studied statistical analysis preprocessors and rule based expert systems to monitor and diagnose HVAC systems. Pape et al. (1991) developed a methodology for fault detection in HVAC systems based on optimal control. In order to detect faults in system operation, deviation from optimal performance was sensed by comparing the measured system power with the power predicted using the optimal control strategy. Norford and Little (1993) presented a method for diagnosing faults in HVAC systems using parametric models of consumed electric power.

Lee et al. (1996a) represented a scheme for detecting faults in an air-handling unit using recursive parameter identification methods. One approach used in that study was to define residuals that represent the difference between the existing state of the system and the normal state. Residuals that are significantly different from zero represent the occurrence of a fault. In a successive investigation by Lee et al. (1996b), they described the application of an artificial neural network to the problem of fault diagnosis. If the system being monitored is complex, isolating the fault can be challenging, and diagnostic tools should be more adaptable for this purpose. They showed that the artificial neural network method can be a good solution to such problems.

Peitsman and Bakker (1996) applied a black-box model to an HVAC system for fault detection. Multi-input and single-output (MISO) autoregressive with exogenous input models and artificial neural network models are used in the study. The whole HVAC system is regarded as a block box instead of as a collection of component models. With the component model type, the components of the HVAC system are regarded as separate black boxes.

Only recently have investigators begun to examine FDD techniques for vapor compression systems rather than the broader area of the whole HVAC system. FDD for vapor compression systems was initially intended to help technicians servicing individual vapor compression systems. Grimmelius (1995) developed an on-line failure diagnosis system for a vapor compression refrigeration system used in a naval vessel or a refrigerated plant. He established a symptom matrix based on the combination of casual analysis, expert knowledge, and simulated failure modes. Using fuzzy logic, a real-time recognition of the failure model was suggested. The author commented on the need to develop more general skills for reference state estimation, on insensitive pattern recognition routines for failure models, and on transient diagnostic models.

Stylianou and Nikanpour (1996) represented a methodology using thermodynamic modeling, pattern recognition, and expert knowledge to determine the health of a reciprocating chiller and to diagnose selected faults. The authors suggested three fault detection modules for startup, stop, and steady-state operations based on a thermodynamic model and expert knowledge of the chiller. They tried to deal with the sensor drift fault when the chiller was off. In a successive investigation, Stylianou (1997) presented a fault diagnostic methodology using a Bayesian decision rule which assigned different faults, including no-fault, status to single classes.

Rossi and Braun (1997) developed a statistical FDD method for a roof-top air conditioner. The fault diagram was developed with temperature measurements. The residual values are used as performance indices for both fault detection and diagnosis. Statistical properties of the residuals for current and normal operation are used to classify the current operation as faulty or normal. Five kinds of faults can be distinguished from the diagnosis. They suggested a fault detection classifier and a fault diagnostic classifier. The fault detection classifier module was based on a Bayesian decision rule, and the fault diagnostic classifier module was developed assuming individual features as a series of independent probabilistic accidents.

Breuker and Braun (1998) surveyed frequently occurring faults for a packaged air conditioner using field data. Based on the field data, Breuker and Braun sorted field faults into three different categories according to the cause of the fault, service frequency, and service cost. With respect to the cause of the fault, system shutdown failures were caused by electrical or control problems approximately 40 % of the time and mechanical problems approximately 60 % of the time. When sorted by service frequency, refrigerant leakage occurs most frequently, followed by condenser, air handling, evaporator, and compressor faults. When sorted by service cost, compressor failure contributes 24 % of total service costs. Control related faults contribute 10 % of total service costs.

Chen and Braun (2001) developed a simplified FDD method for a 17.6 kW (5 ton) rooftop air conditioner with a TXV. They modified an FDD technique by simplifying Rossi and Braun's method (1997). They used measurements and model predictions of temperatures for normal system operation to compute ratios which were sensitive to individual faults. They also proposed a simple rule-based FDD process of sequential rules developed by comparing the sensitivity of residuals organized within a fault characteristic chart.

Castro (2001) applied a k-nearest neighbor and k-nearest prototype method for fault detection of a chiller. The author calculated Euclidean distances for the current state based on the selected two largest residuals, and estimated the possibility of a fault from the distance information. In this research, the software MATCH was developed as a tool for the controls package to combine monitoring, fault detection, and diagnostic features. After detecting faults, data deemed faulty were input to the rule-based fault diagnosis algorithm. Castro preferred the nearest prototype classifier since the nearest neighbor classifier is more computationally intensive.

Comstock and Braun (2001) tested eight common faults in a 316 kW (90 ton) centrifugal chiller to identify the sensitivity of different measurements to faults. The identification of common faults was determined through a fault survey among major American chiller manufacturers. The fault testing led to a set of generic rules for the impacts of faults on measurements that could be used for FDD. Impact of faults on cooling capacity and coefficient of performance were also evaluated.

Smith and Braun (2003) performed field-site tests on more than 20 units to identify local installation and operation problems. Using a 10.6 kW (3 ton) rooftop unit with a fixed orifice expansion device and a 17.6 kW (5 ton) unit with a TXV, the FDD problem was formulated in a mathematical way and a decoupling based unified FDD technique was proposed to handle multiple simultaneous faults. Li (2004) re-examined the statistical rule-based method initially formulated by Rossi and Braun (1997) and presented two additional FDD schemes which improved the sensitivity of the FDD module. He also provided virtual sensors to estimate characteristic parameters from indirect component modeling. For a reference model, Li combined a multivariate polynomial model and a generalized regressive neural network (GRNN).

Kim and Kim (2005) tested a water-to-water heat pump system with a variable speed compressor and an electrical expansion valve (EEV). From the research, the system parameters are found to be less sensitive to faults compared to a constant speed compressor system. They reported that controlling the compressor speed suppressed the changeability of the system. They also provided an FDD algorithm along with two different rule-based charts depending on the compressor status. Kim and Kim suggested that COP degradation due to a fault is much more severe with a variable speed compressor than with a constant speed compressor.

2.3 Research Objective

The objective of this research was to test a heat pump operating in the cooling mode in order to map system parameters during no-fault and imposed-fault operation. System status was monitored, and performance parameters were recorded. Seven faults were imposed: 1) compressor valve leakage, 2) outdoor improper air flow, 3) indoor improper air flow, 4) liquid line restriction, 5) refrigerant undercharge, 6) refrigerant overcharge, and 7) presence of non-condensable gas. The follow-up study will use the collected results for the development of FDD methods.

CHAPTER 3. EXPERIMENTAL SETUP AND TEST PROCEDURE

3.1 System Selected for Testing

The studied system was an R410A split residential heat pump of a 8.8 kW (2.5 ton) nominal cooling capacity and Seasonal Energy Efficiency Ratio (SEER) of 13. The unit is comprised of the indoor fan-coil section, outdoor section with a compressor, a thermostatic expansion valve (TXV), and connecting tubing. Both the indoor and outdoor air-to-refrigerant heat exchangers were of the finned-tube type. The unit was installed in NIST's environmental chambers and charged with refrigerant according to the manufacturer's specifications.

Figure 3.1 shows the outdoor section. A flow guide was attached to the top of the unit to aid in the traverse of a hot wire anemometer. The coil had 81 cm x 175 cm (32 in x 69 in) of finned area, with 7 fins/cm (18 fins/in) of a wavy-lanced type fins. Figure 3.2 shows a schematic of the outdoor unit refrigerant circuitry.

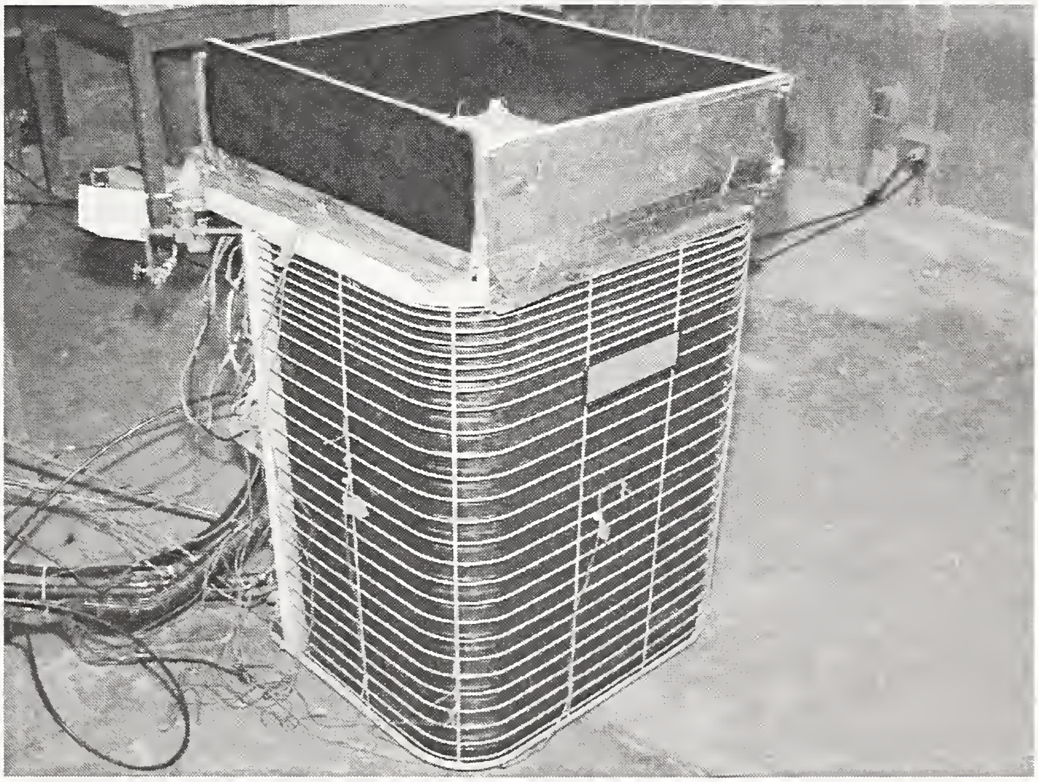


Figure 3.1. Side view of the outdoor section with the flow guide

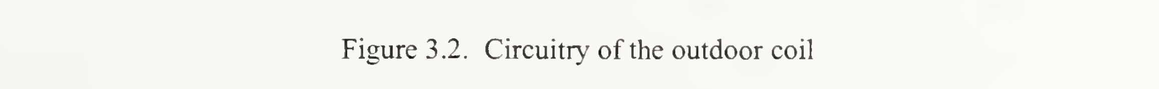


Figure 3.2. Circuitry of the outdoor coil

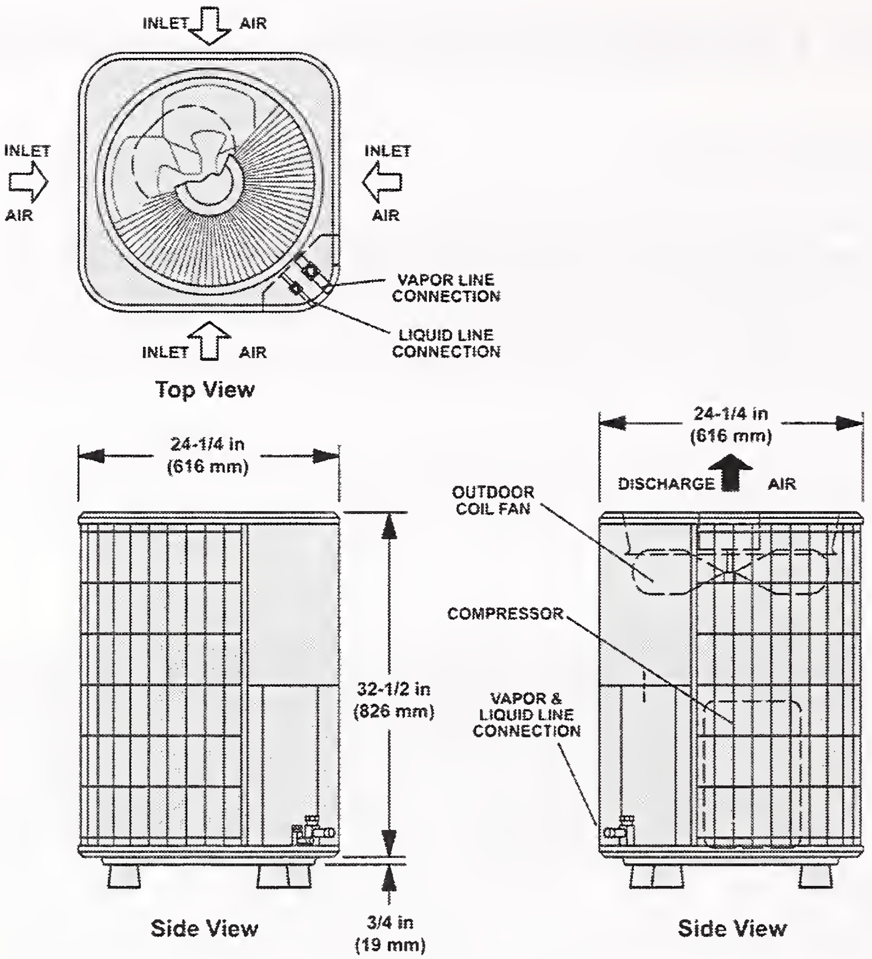


Figure 3.3. Outdoor section dimensions

The circles denote the tubes, the continuous lines indicate the return bends on the near side of the heat exchanger, and the broken lines indicate the return bends on the far side. As Figure 3.2 shows, the outdoor coil had five inlets and five outlets, i.e., it had five independent circuitry branches. Figure 3.3 presents a graphical representation and dimensions of the outdoor unit.

Figure 3.4 shows the side view of the indoor coil assembly. It comprised two identical slabs and was designed for air flow from the bottom to the top. The two slabs had an included angle of 60° in an A-shape. Each slab of the coil had 48.5 cm x 43 cm (19 in x 17 in) of finned area with 5 fins/cm (13 fins/inch) of the wavy-lanced type. Figure 3.5 shows the refrigerant circuitry for both slabs. Each slab had two inlets from the TXV and two outlets connected to the suction manifold. Figure 3.6 shows the configuration and outside dimensions of the indoor fan-coil unit. The air flow rate through the coil was approximately 28.3 m^3/min (1000.0 scfm). Fin thickness for both the indoor and outdoor coils was 0.12 mm (0.0047 in).

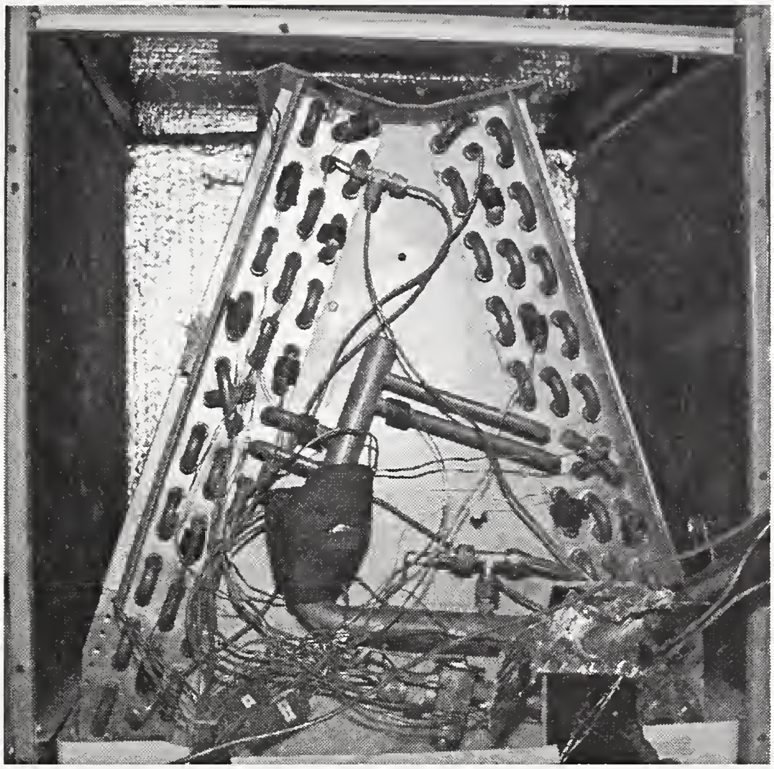


Figure 3.4. Side view of the indoor coil and upflow duct

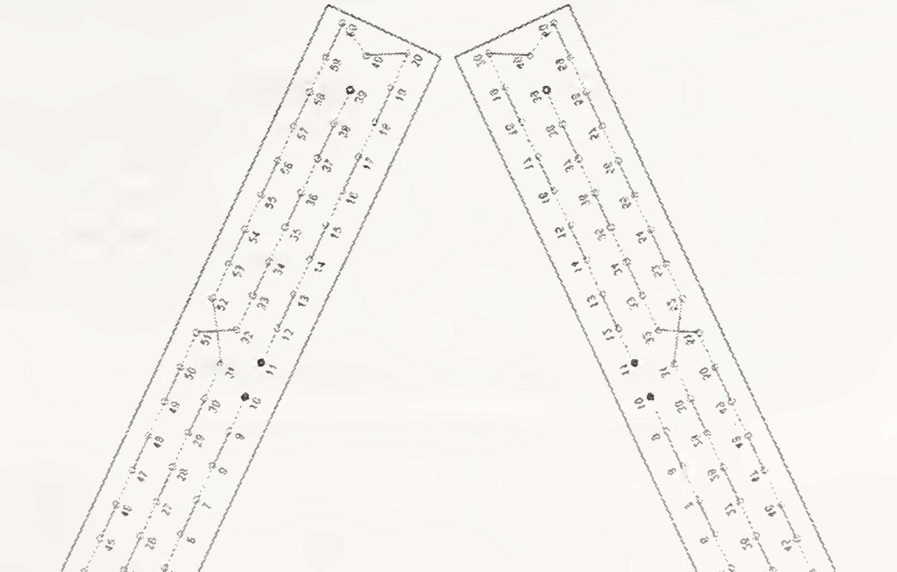


Figure 3.5. Circuitry of indoor coil

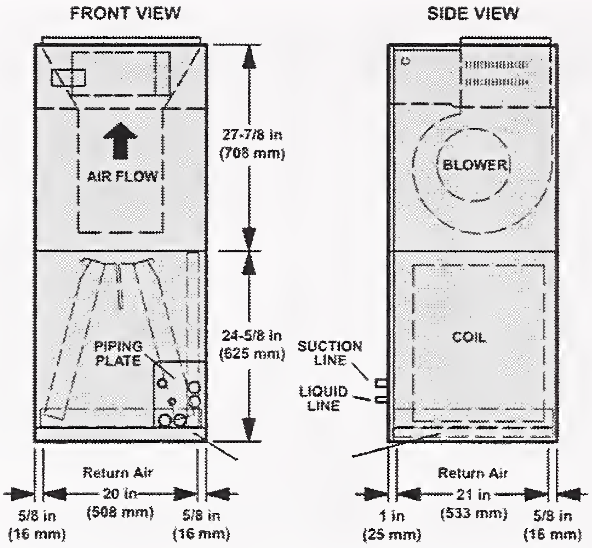


Figure 3.6. Indoor fan-coil unit dimensions

3.2 System Setup and Instrumentation

Figure 3.7 shows the air duct arrangement in the indoor environmental chamber. The ductwork was constructed according to the applicable standards (ANSI/ASHRAE Standard 51, ANSI/ASHRAE Standard 37). The air was pulled through the test apparatus by a centrifugal fan located at the outlet of the nozzle chamber ductwork. Figure 3.8 shows the schematic diagram of the heat pump installation. On the air side, the setup involved measurements of dry-bulb and dew-point temperatures, barometric pressure and pressure drop. Dew-point temperature was measured at the inlet of the evaporator ductwork and downstream the evaporator and air mixers. Twenty-five node, T-type thermocouple grids and thermopiles measured air temperatures and temperature change, respectively.

On the refrigerant side, pressure transducers and T-type thermocouple probes were attached at the inlet and exit of every component of the system to take the actual refrigerant pressure and temperature. The refrigerant mass flow rate was also measured using a Coriolis flow meter. The measurements of temperature, pressure, and mass flow rate took place in the locations indicated in Figure 3.8. The air enthalpy method served as the primary measurement of the system capacity, and the refrigerant enthalpy method served as the secondary measurement. These two measurements always agreed within 5 %. Additionally, compressor power was measured for calculations of the coefficient of performance (COP). Appendix A lists the measuring devices including the measurements shown in Figure 3.8. Table 3.1 lists characteristic uncertainties of the major quantities measured during this work.

Table 3.1. Measurement uncertainties

Measurement	Range	Total Uncertainty at the 95 % Confidence Level
Individual Temperature	-18 °C to 93 °C (0 °F to 200 °F)	±0.3 °C (±0.5 °F)
Temperature Difference	0 °C to 28 °C (0 °F to 50 °F)	±0.3 °C (±0.5 °F)
Air Nozzle Pressure	0 Pa to 1245 Pa (0 in H_2O to 5.0 in H_2O)	±1.0 Pa (±0.004 in H_2O)
Refrigerant Mass Flow Rate	0 kg/h to 544 kg/h (0 lbm/min to 20 lbm/min)	±1.0 %
Dewpoint Temperature	(32°F to 100 °F)	±0.4 °C (0.8 °F)
Dry-Bulb Temperature	(35 °F to 100 °F)	±0.4 °C (0.8 °F)
Total Cooling Capacity	(15 000 Btu/h to 36 000 Btu/h)	4.0 %
COP	2.5 to 6.0	5.5 %

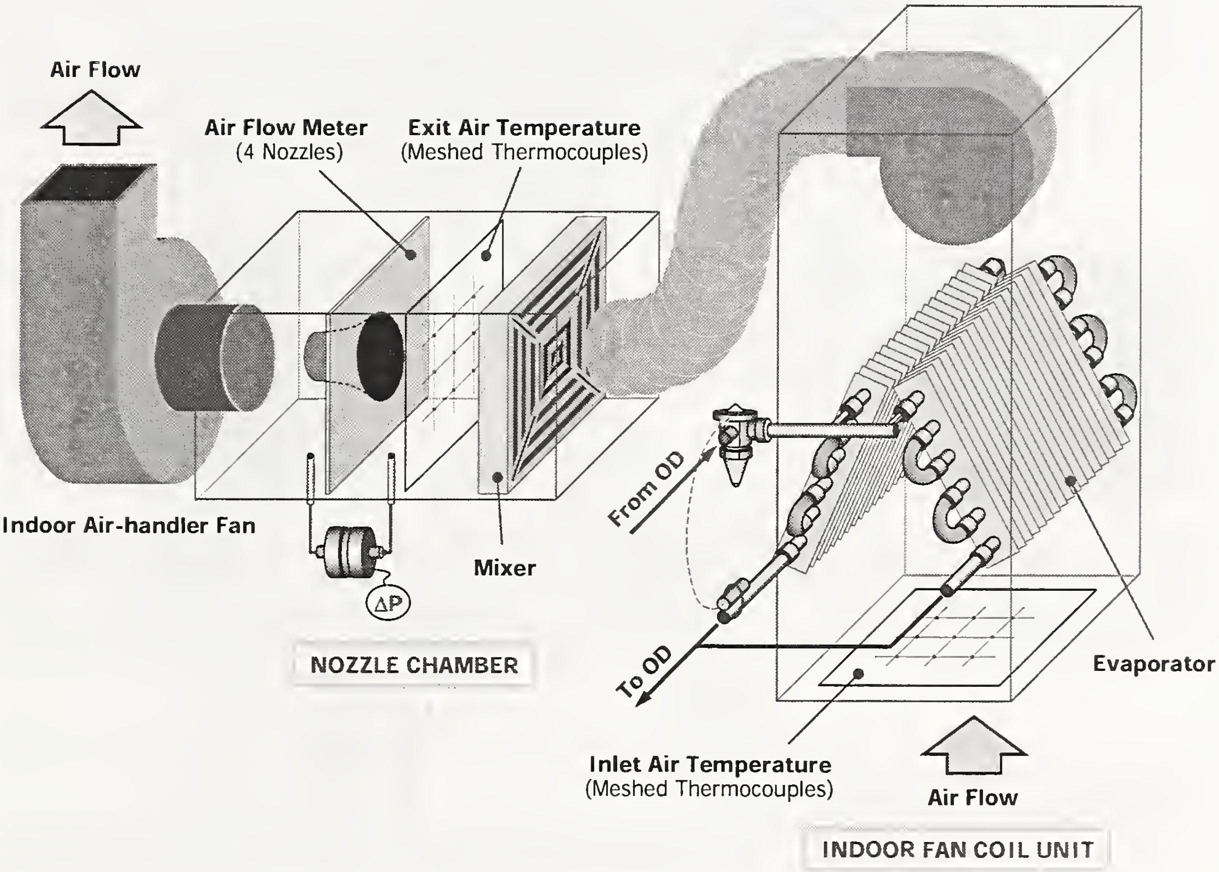


Figure 3.7. Air duct arrangement in the indoor environmental chamber

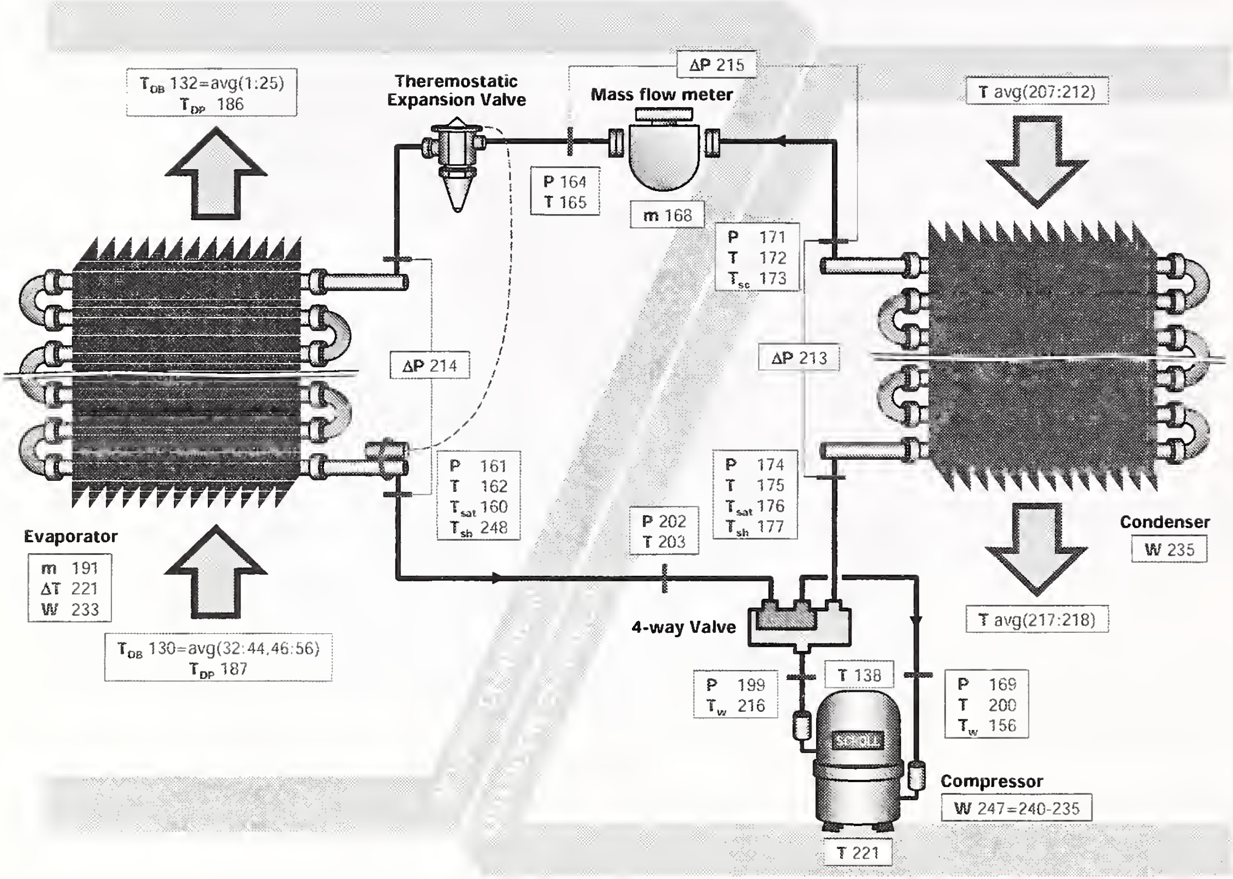


Figure 3.8. Experimental setup with the heat pump in the cooling mode

3.3 Implementation of Artificial Faults

Table 3.1 lists the seven types of common faults which were investigated in this study. The improper indoor air flow, liquid line restriction, refrigerant overcharge, refrigerant undercharge, and presence of a non-condensable gas (air) may result from improper installation. All faults in Table 3.1, except the presence of non-condensables, may also appear in the system after installation over the life of the heat pump. The respective causes may be compressor valve wear, outdoor coil fouling, a dirty air filter or coil fouling, dirty filter/dryer, improper recharge service, and a refrigerant leak. These seven faults and their implementation during tests are discussed in more detail in the sections below.

Table 3.2. Description of studied faults

Fault	Abbr.	Determination of level of fault during tests
Compressor leakage (4-way valve leakage)	CMF	% of refrigerant flow rate
Improper outdoor air flow rate	CF	% of coil area blocked
Improper indoor air flow rate	EF	% of correct air flow rate
Liquid line restriction	LL	% of normal pressure drop through TXV
Refrigerant overcharge	OC	% overcharge from the correct charge
Refrigerant undercharge	UC	% undercharge from the correct charge
Presence of non-condensable gases	NON	% of non-condensable gas

3.3.1 Compressor/reversing valve leakage

Compressor faults can arise from various reasons: gas leakage, improper lubrication, motor failure, etc. Brueker and Braun (1998) indicated that approximately 70 % of the classified faults are associated with a motor problem; motor performance degradation may be a result of overloading due to condenser fouling or a high outdoor temperature. Unstable electrical power - such as high/low voltage and voltage spike - can also cause motor problems.

The second major compressor fault is due to compressor valve leakage or other leakage which decreases the refrigerant mass flow rate. Wear and tear related to long-time operation of a reciprocating compressor may cause the refrigerant to leak through the suction or discharge valve. For scroll compressors, the refrigerant may leak in tangential directions through radial clearances between the neighboring pockets (flank leakage or tangential leakage) or in the radial direction through axial clearances between the rotating scroll and the body (tip leakage or radial leakage). Improper lubrication can degrade compressibility due to abrasion of contact surfaces like piston rings or cylinder walls. The internal bypasses can arise from the intrusion of liquid refrigerant into the compressor. When the system starts up at low ambient temperatures or has the following faults: evaporator/condenser fouling, refrigerant overcharge, or excessively opened TXV, the compressor suction chamber may be flooded by liquid refrigerant. When the liquid refrigerant intrudes repeatedly into the compressor cylinder, mechanical parts like valves, rods, and piston will be damaged. Each of these faults degrades compression efficiency, whereas fatal compressor breakdown may halt the entire system.

In this research we simulated an internal leak in the compressor by implementing a hot gas bypass shown in Figure 3.9. For no-fault tests, the shut-off valve ensured no refrigerant flow through the bypass. During tests simulating a faulty compressor, fine tuning of the metering valve and a larger crude valve allowed establishment of a desired refrigerant flow rate through the bypass from the compressor discharge line to the suction line.

We expressed the severity of the artificial compressor leak as the reduction of refrigerant mass flow rate as compared to a no-fault condition. For each operating condition we performed a no-fault test first (with the shut-off valve closed) to obtain the reference mass flow rate. Then, we activated the bypass, and measured the new refrigerant mass flow rate, which was used for calculating the fault level. Refrigerant leakage through a 4-way valve would affect the system performance similarly to the compressor leakage.

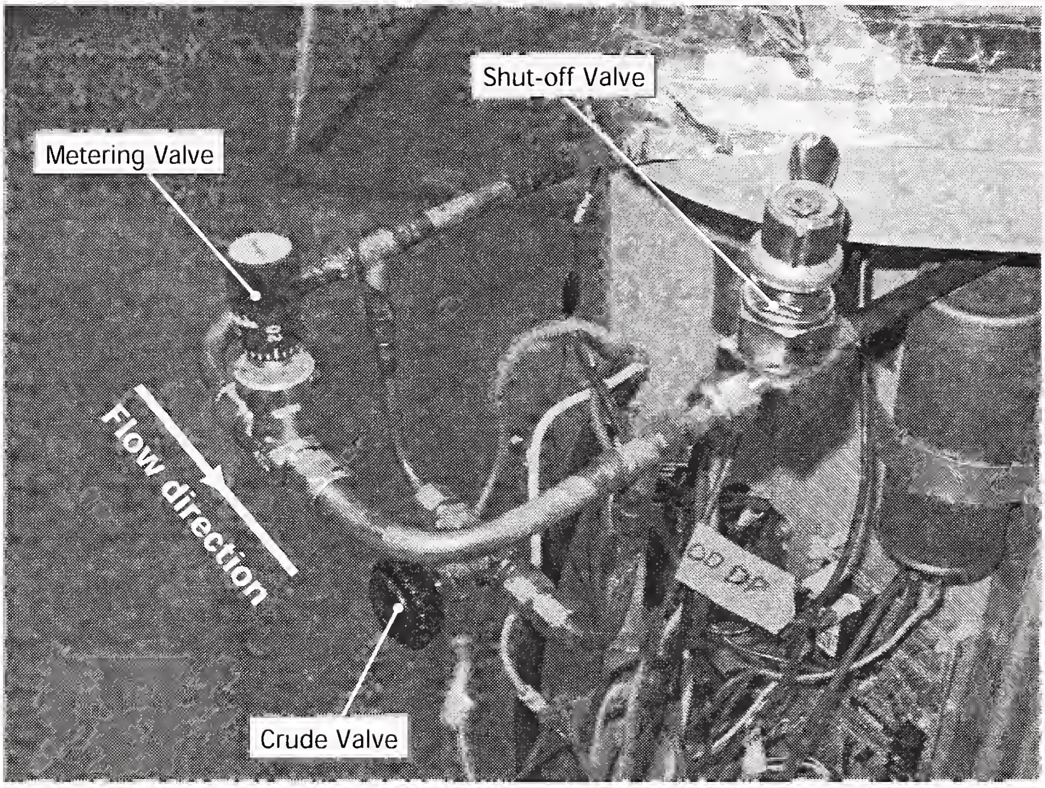


Figure 3.9. Hot gas bypass used for compressor/reversing valve leakage fault

3.3.2 Improper outdoor air flow rate

Outdoor sections are exposed to the outdoor environment and are easily contaminated by dirt or debris. Sometimes outdoor sections are surrounded by overgrown weeds or fallen leaves which restrict the air flow to the outdoor heat exchanger. The outdoor air flow may also decrease because of a defective fan motor, loose fan belt, or a poorly installed controller.

We simulated fouling of the outdoor heat exchanger by blocking the bottom part of its finned area with paper strips. The fault level was the percentage of the outdoor coil face area blocked by paper. Figure 3.10 shows the outdoor coil with a blockage or fault level of 35 %.

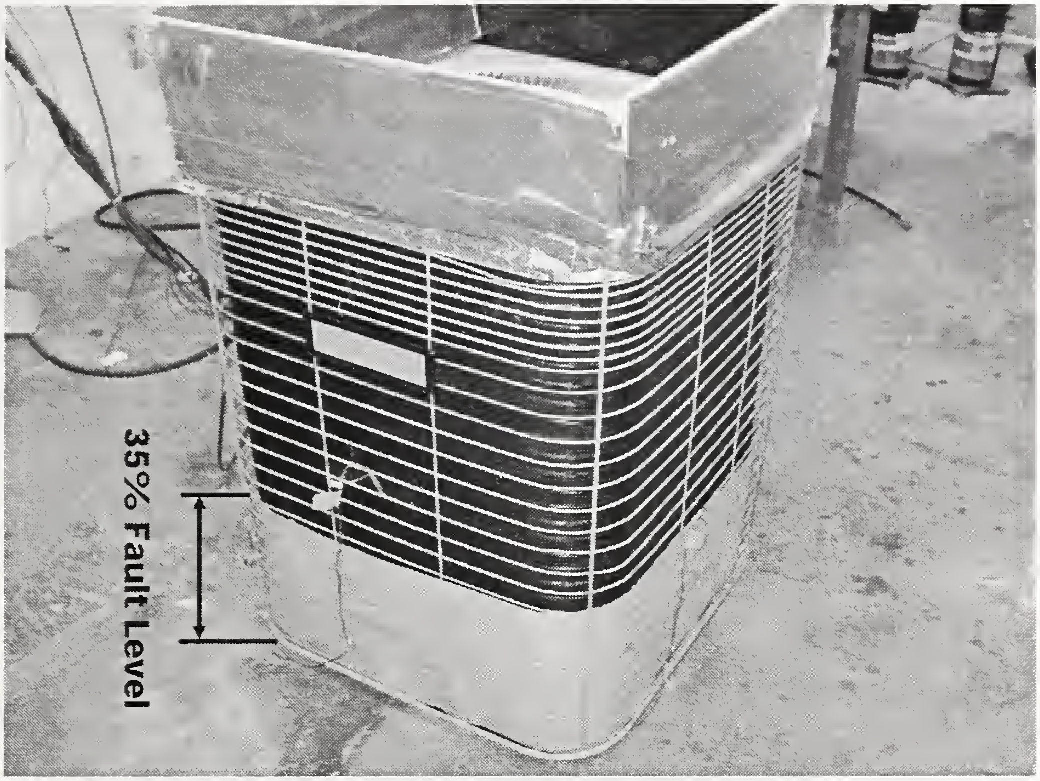


Figure 3.10. Condenser with lower finned area blocked (35 % of the entire finned area blocked)

3.3.3 Improper indoor air flow rate

The air flow rate through the indoor section is affected by the size of ductwork, indoor fan sizing, and duct contamination. An improper duct design may burden the fan with an excessive load causing the fan to work below the nominal speed. Dust and debris collected on the heat exchanger may also result in a reduction in the air flow rate. Household articles like textile goods and carpets produce chemically reactive dust, and kitchens and baths also generate chemical vapor. If air filters are not maintained in good condition, these particles can flow into the ductwork and stick on the fan coil unit and duct walls reducing the air flow rate.

For this study the no-fault, reference air mass flow rate was set to 28.3 m^3/min (1000 scfm). For faulty tests, we reduced the speed of the nozzle chamber fan at the end of ductwork (see Figure 3.7). The fault level was the percent change in air mass flow rate with respect to the reference mass flow rate measured at no-fault conditions.

3.3.4 Liquid line restriction

Typically, a filter/dryer is installed in the liquid line to remove moisture and any solid particles from the circulating refrigerant. Moisture may enter the system if a service technician does not follow good refrigerant charging practices during servicing, while some rust may exist in the system because of improper tube joinery technique. Accumulation of these substances will block the filter/dryer and unduly increase the refrigerant flow restriction.

To simulate an increased liquid line flow restriction, we installed a shut-off valve and metering valve in the liquid refrigerant line in a parallel configuration displayed as shown in Figure 3.10. By modulating the two valves, we controlled the liquid line restriction. The level of the liquid line restriction fault was the percent change in the liquid line pressure drop with respect to the pressure differential between the condenser exit and the evaporator inlet at the no-fault condition.

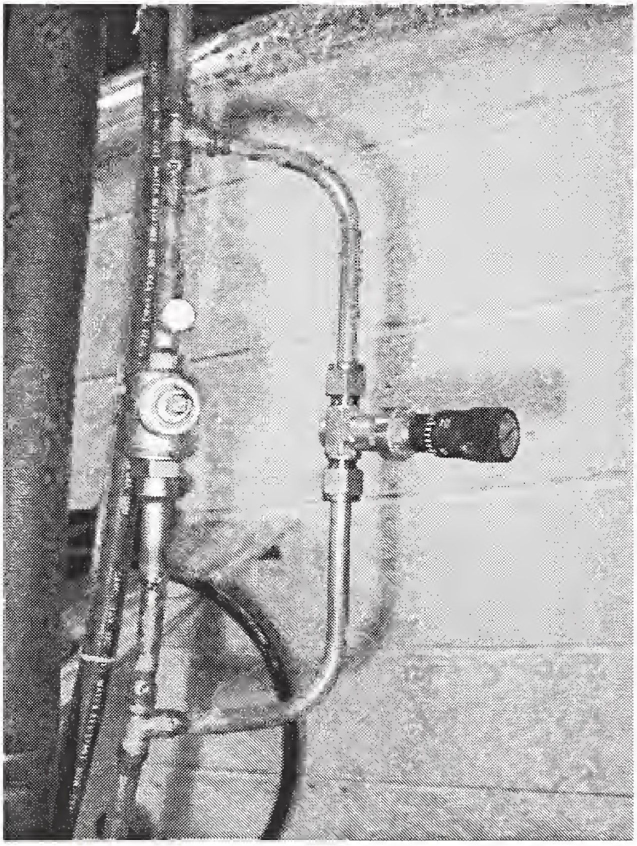


Figure 3.11. Artificial setup to implement a liquid line restriction fault using a shut-off valve and a metering valve

3.3.5 Refrigerant undercharge and overcharge

Residential systems are charge sensitive, i.e., their performance is influenced by the amount of refrigerant in the system. Refrigerant overcharge is a result of improper charging by a service technician. Refrigerant undercharge may result from improper charging or from a refrigerant leak. A rapid leak, caused by a component failure such as a fractured heat exchanger wall, is easy to detect because it degrades the system performance abruptly (a so called "hard fault"). A slow leak – e.g., due to a bad fitting in the refrigerant line where a small portion of refrigerant leaks for a long time – is typically difficult to detect, because the change in performance is slow and gradual (a so called "soft fault"). We simulated the overcharge and undercharge faults by adding or reducing the amount of refrigerant in the system. We determined the level of fault as the mass percentage of overcharged or undercharged refrigerant with respect to the optimized no-fault total refrigerant charge.

The improper charge was set by adding more or less refrigerant to the system, but keeping the same amount of POE (polyester) oil. The charge level was established in reference to nominal charge, assumed as 100%. A charge of 4.65 kg of R410A was taken as reference following the manufacturer's optimum charging criteria.

3.3.6 Presence of non-condensable gases

Before charging a system with a refrigerant, the system should be evacuated below 500 mTorr (0.02 inHg absolute) to remove the air and moisture. When a service technician uses a defective vacuum pump or does not operate it correctly, some air and moisture will remain in the system. This air may be particularly detrimental to systems using polyol ester lubricants, which absorb about 10 times more moisture from air than mineral oils and alkyl benzene. (For this reason polyol ester lubricants are packaged with a nitrogen blanket as a moisture barrier and are stored in metal containers rather than plastic since moisture migrates over time through plastic.)

Non-condensable gases raise condensing pressure, which degrades the compressor efficiency and increases energy consumption. A TXV can malfunction at unduly elevated system pressures. The compressor can be damaged in an extreme case.

In this research we injected dry nitrogen gas to simulate non-condensable gas intrusion into the system. Atmospheric pressure nitrogen was set as a 100 % fault level. Fault level was determined as the proportion of injected mass of nitrogen to the nitrogen mass constituting a 100 % fault (completely filling up the internal volume of the system at atmospheric pressure).

3.4 Experimental Procedure and Test Conditions

We executed a comprehensive test series to map the performance of the system at normal (no-fault) operation and with imposed faults. Table 3.2 presents operating conditions for the test program at no-fault conditions. For indoor conditions, the test program included two temperatures, 21.1 °C (70.0 °F) and 26.7 °C (80.0 °F), and two levels of relative humidity, 50 % and dry coil. For outdoor conditions, we selected four temperatures: 21.1 °C (70.0 °F), 27.8 °C (82.0 °F), 32.2 °C (90.0 °F), and 37.8 °C (100.0 °F). Outdoor relative humidity is not an influential parameter for performance of the condenser, and it was controlled roughly around 50 % within the range of 40 % to 60 %.

The test schedule for no-fault steady-state involved 17 indexed cases; one ARI 210/240 Standard rating test and 16 full factorial combinations of chamber conditions; 2 indoor temperatures × 2 indoor humidities × 4 outdoor temperatures = 16 tests. The fault tests were carried out for four operating conditions indicated in Table 3.2 by two asterisks (tests 4, 5, 8, and 9). All no-fault tests were performed twice to check experimental repeatability. In addition, a no-fault test preceded a series of tests carried out for a given fault at each of the four operating conditions.

Table 3.3 shows the primary set of tests. The tests listed include the repeatability tests, and transient tests. In total, the table lists 257 tests. The installation of the system, measurements, and data reduction were performed according to the applicable standards (ASHRAE Standard 37, ARI 210/240 Standard).

Table 3.3. Operating conditions for no-fault tests

Test index	Indoor		Outdoor	
	Dry-bulb temp. °C (°F)	Relative humidity %	Dry-bulb temp. °C (°F)	Relative humidity %
1*	26.7 (80.0)	50	35.0 (95.0)	40 to 60
2	21.1 (70.0)	50	21.1 (70.0)	40 to 60
3	26.7 (80.0)	50	21.1 (70.0)	40 to 60
4**	21.1 (70.0)	50	27.8 (82.0)	40 to 60
5**	26.7 (80.0)	50	27.8 (82.0)	40 to 60
6	21.1 (70.0)	50	32.2 (90.0)	40 to 60
7	26.7 (80.0)	50	32.2 (90.0)	40 to 60
8**	21.1 (70.0)	50	37.8 (100.0)	40 to 60
9**	26.7 (80.0)	50	37.8 (100.0)	40 to 60
10	21.1 (70.0)	dry coil	21.1 (70.0)	40 to 60
11	26.7 (80.0)	dry coil	21.1 (70.0)	40 to 60
12	21.1 (70.0)	dry coil	27.8 (82.0)	40 to 60
13	26.7 (80.0)	dry coil	27.8 (82.0)	40 to 60
14	21.1 (70.0)	dry coil	32.2 (90.0)	40 to 60
15	26.7 (80.0)	dry coil	32.2 (90.0)	40 to 60
16	21.1 (70.0)	dry coil	37.8 (100.0)	40 to 60
17	26.7 (80.0)	dry coil	37.8 (100.0)	40 to 60

* ARI Standard 210/240 (2006)

** Combination of test conditions selected for fault tests

Table 3.4. Primary tests

Tests	Types of tests	Number of tests
No-fault	16	82
Individual faults	98	118
Dynamic tests	6	12
ARI check	5	5
Total	177	257

CHAPTER 4. NO-FAULT TESTS AND SYSTEM CHARACTERISTICS

4.1 Identification of Steady State

Most FDD schemes applied to various types of equipment detect and diagnose faults during steady-state operation. In this study, we envision the FDD process to be performed every time the system is in steady state, or more precisely, when the system is statistically identified to be nearly in a steady state.

Steady state can be detected by observing the entire system, or – more simply – by monitoring selected system parameters. If the goal was to check the system performance, providing enough time to reach steady-state capacity could be a sufficient approach. However, reaching a steady capacity would not guarantee the actual steady state of all parameters used in a particular FDD scheme. Since steady-state schemes are widely used in fault detection, identification of steady-state operation is an important task for satisfactory FDD analysis.

A steady-state detector makes the determination as to whether the system operates in a steady state. The concept of the steady-state detector originates from a noise filter. When parameter measurements are unstable, they are said to be affected by noise, or the system is regarded as being in a transient state. The standard deviation of these measurements indicates the statistical spread in the data distribution, and it can be used to characterize random variation of the measured signal. The system is far from steady-state operation when the standard deviation is large. There are many different ways to design a steady-state detector, but the most common ones have their roots in simple averaging over a predefined moving time window (see Figure 4.1).

In this research, we selected the evaporator exit refrigerant superheat and liquid line refrigerant subcooling as the parameters used for steady-state detection. We applied a steady-state detector which uses the calculation of the mean and standard deviation of these parameters in a recursive fashion. A recursive solution depends on a previously calculated value. Suppose that at any instant *k*, the average of the latest *n* samples of a data sequence, x_i, is given by,

$$\bar{x}_k = \frac{1}{n} \sum_{i=k-n+1}^{k} x_i \tag{4.1}$$

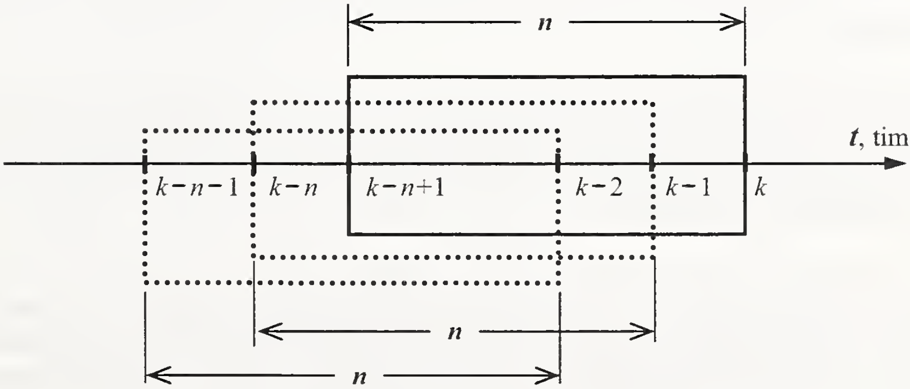


Figure 4.1. Moving windows of *n* data points at near k^{th} time

A difference between two averages of the latest n samples at the current time, k, and at the previous time instant, $k-1$, is,

$$\bar{x}_k - \bar{x}_{k-1} = \frac{1}{n}\left[\sum_{i=k-n+1}^{k} x_i - \sum_{i=k-n}^{k-1} x_i\right] = \frac{1}{n}\left[x_k - x_{k-n}\right] \tag{4.2}$$

Rearranged, the current average is calculated by,

$$\bar{x}_k = \bar{x}_{k-1} + \frac{1}{n}\left(x_k - x_{k-n}\right) \tag{4.3}$$

This approach is known as a moving window average because the average at each k^{th} instant is based on the most recent set of n values. In other words, at any instant, a moving window of n values is used to calculate the average of the next data sequence.

A moving window variance can be defined similarly. Suppose the variance of the latest n samples is

$$v_k = \frac{1}{n}\sum_{i=k-n+1}^{k} \left(x_i - \bar{x}_k\right)^2 = \frac{1}{n}\sum_{i=k-n+1}^{k} x_i^2 - \bar{x}_k^2 . \tag{4.4}$$

Therefore,

$$v_k = v_{k-1} + \frac{1}{n}\left(x_k^2 - x_{k-n}^2\right) - \left(\bar{x}_k^2 - \bar{x}_{k-1}^2\right) \tag{4.5}$$

Moving window standard deviation is given as

$$\sigma_k = \sqrt{v_k} . \tag{4.6}$$

The steady state detector identified steady-state operation if the standard deviations for the evaporator exit refrigerant superheat and liquid line refrigerant subcooling fell below the pre-specified threshold value of 0.44 °C (0.8 °F). The size of the moving window was set to 5 samples at 78 second intervals.

4.2 Variation of Measured Signals

The performance of an FDD system is closely related to the performance of its sensors. Before developing any FDD system, required sensor accuracy and sensor cost should be evaluated. Cost issues are improving as new sensor technologies are developed; however, there always exist unavoidable uncertainties for measurement systems.

Fundamentally, every sensor has its own uncertainty. When a system is tested with various measurement sensors, uncertainties such as random error (measurement noise, signal noise) and bias error (systematic error) may appear. Uncertainties due to signal noise can be classified as random error which is associated with noise from the instrumentation system and from short-term variations in the process being measured. Measurement noise is similar in shape to sound wave white noise. Normally measurement noise is less than other uncertainties, but in some cases the measurement noise may be severe, e.g., when electrical equipment such as inverters, turbines, and compressors generate strong electromagnetic fields. Some sensors are so sensitive to external noise that even slight interference can influence the measurement. In these cases, the sensor should be properly shielded from the noise in order to prevent the measurement from being distorted.

In this research, test conditions are specified by three parameters: outdoor temperature, indoor temperature, and indoor humidity. Figure 4.2 shows the variation of indoor chamber temperature at a setpoint of 21.1 °C (70.0 °F). The data in the figure were collected after the system was at steady state. Figure 4.2(a) shows a 40 min variation of one of the temperature sensors at the inlet air duct thermocouple grid with a sampling interval of 78 s. As seen in the plot, indoor temperature is stabile but has fluctuation. In the fluctuation, the effect of random error is dominant compared to the thermocouple measurement total error, i.e., the measurement does not appear to have a bias error. Figure 4.2(b) shows indoor dry bulb temperature for 17 different experiments with a sampling size of 10 measurements. The indoor temperature setpoint was 21.1 °C (70.0 °F). The stepped horizontal solid lines represent the average of each experiment, and the thick solid line (m) is the overall average of the indoor temperature for all of the 17 experiments.

4.3 Multivariate Polynomial Reference Model

The objective of the no-fault tests was to take measurements at different environmental operating conditions at different system locations to formulate key systems parameters – referred to as features – and to develop models to correlate these parameters. In this research the outdoor dry-bulb temperature, T_{OD}, indoor dry-bulb temperature, T_{ID}, and indoor dew-point temperature, T_{IDP}, are the independent variables that define operating conditions. All features, ϕ_i, can be explicitly described by multivariate polynomials correlated to the no-fault experimental data. Equations 4.7a, 4.7b, and 4.7c represent general formulations of 1st, 2nd, and 3rd order multivariate polynomial equations using the independent variables, respectively.

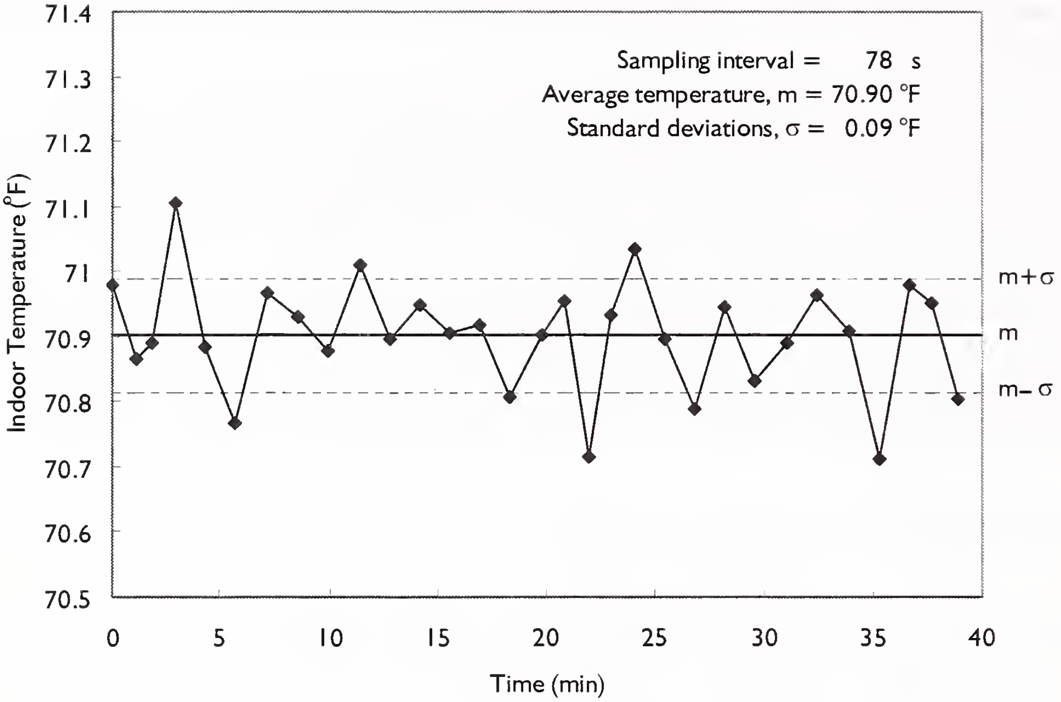
$$\phi_i = a_0 + a_1 T_{OD} + a_2 T_{ID} + a_3 T_{IDP} \tag{4.7a}$$

$$\phi_i = a_0 + a_1 T_{OD} + a_2 T_{ID} + a_3 T_{IDP} + a_4 T_{OD} T_{ID} + a_5 T_{ID} T_{IDP} + a_6 T_{IDP} T_{OD} + a_7 T_{OD}^2 + a_8 T_{ID}^2 + a_9 T_{IDP}^2 \tag{4.7b}$$

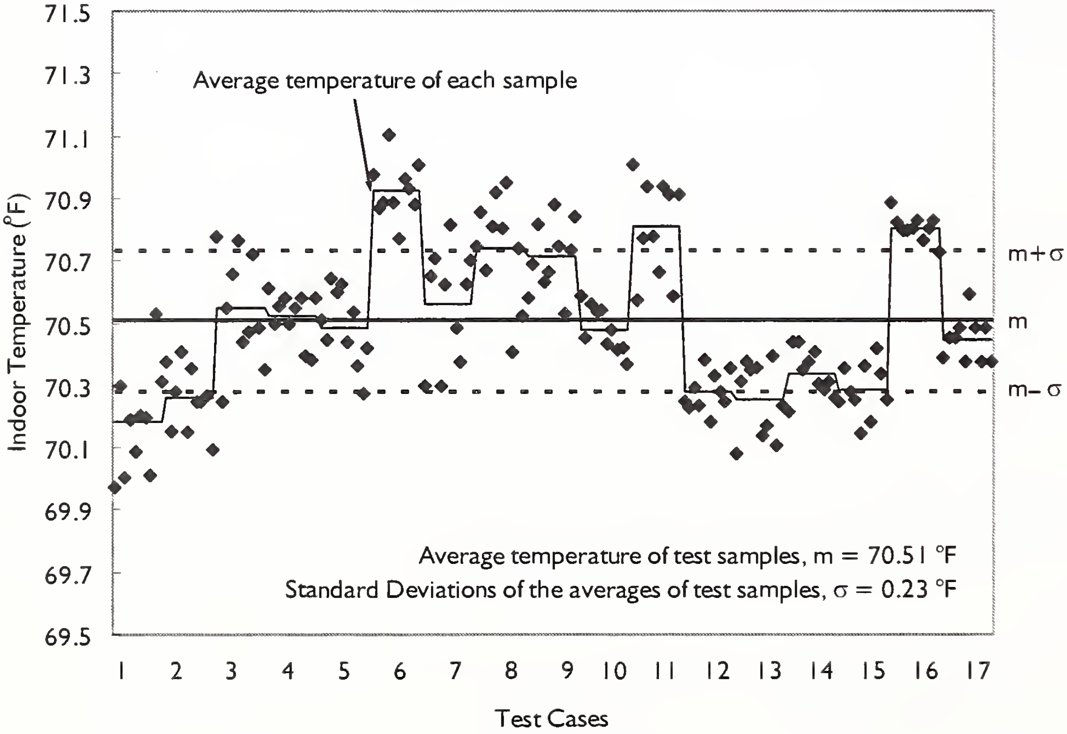
$$\begin{aligned}\phi_i = {} & a_0 + a_1 T_{OD} + a_2 T_{ID} + a_3 T_{IDP} + a_4 T_{OD} T_{ID} + a_5 T_{ID} T_{IDP} + a_6 T_{IDP} T_{OD} + a_7 T_{OD}^2 + a_8 T_{ID}^2 + a_9 T_{IDP}^2 \\ & + a_{10} T_{OD}^2 T_{ID} + a_{11} T_{OD} T_{ID}^2 + a_{12} T_{ID}^2 T_{IDP} + a_{13} T_{ID} T_{IDP}^2 + a_{14} T_{IDP}^2 T_{OD} + a_{15} T_{IDP} T_{OD}^2 \\ & + a_{16} T_{OD}^3 + a_{17} T_{ID}^3 + a_{18} T_{IDP}^3\end{aligned} \tag{4.7c}$$

The 1st order polynomial equation requires only 4 coefficients which may offer only a rough estimate of the reference. The 3rd order polynomial requires 19 coefficients, which is too many coefficients. In this research, all the features selected are estimated using 2nd order polynomials with 10 coefficients, which estimate the reference with acceptable accuracy. The coefficients of selected features are listed in Appendix C.

In the latter sections of this report, eight features are plotted for graphical presentation: T_{ER} – evaporator exit refrigerant saturation temperature, ΔT_{sh} – evaporator exit refrigerant superheat; T_{DW} – compressor discharge wall temperature; T_{CR} – condenser inlet refrigerant saturation temperature; ΔT_{sc} – liquid line



(a) Time change of indoor temperature



(b) Repeatability of indoor temperature

Figure 4.2. Random error of indoor temperature measurement

refrigerant subcooling; T_{CA} – condenser air temperature rise; ΔT_{EA} – evaporator air temperature drop; and ΔT_{LL} – liquid line refrigerant temperature drop. The features can be expressed by residuals calculated by Equation 4.8. Here residual is defined as the difference between the measured value and the value calculated by the reference model in Equation 4.7.

$$\mathrm{R}(\phi_i) = \phi_{i,\mathrm{measurements}} - \phi_{i,\mathrm{reference}} \tag{4.8}$$

Even though the environmental chamber's control parameters are preset by an operator at a constant value, the temperature will be different and will have some random and systematic errors. In Figure 4.2(b), all the indoor dry-bulb temperatures were controlled to be 21.1 °C (70.0 °F); however, the obtained temperatures deviated from the target value. As seen in Figure 4.2(b), the 17 cases intended to have 21.1 °C (70.0 °F) indoor temperature do not represent exactly the same conditions. When we compare the raw measurements, these inevitable deviations function like an external noise and should be considered within the uncertainty analysis. However, when the residuals of the measurements are compared, this deviation can be compensated by mathematical model estimation. When the mathematical model evaluates the current status of the system properly, the trend of the residuals will be much clearer.

In addition to the features, the presented results include the following performance parameters: $Q_{\mathrm{EA,sens}}$ – indoor air sensible capacity; $Q_{\mathrm{AE,lat}}$ – indoor air latent capacity; $\mathrm{SHR}_{\mathrm{EA}}$ – indoor air sensible heat ratio; m_{R} – refrigerant mass flow rate; Q_{CR} – condenser refrigerant-side capacity; Q_{ER} – evaporator refrigerant-side capacity; W_{comp} – compressor work; and EER – energy efficiency ratio.

4.4 No-Fault Test Results

Figure 4.3 shows the pressure-enthalpy (P-h) diagram for four tests at the same indoor temperature of 21.1 °C (70.0 °F) and relative humidity of 50 %, and four outdoor temperatures of 21.1 °C (70.0 °F), 27.8 °C (82.0 °F), 32.2 °C (90.0 °F), and 37.8 °C (100.0 °F) (tests 2, 4, 6, and 8 of Table 3.2). The figure shows that the specific enthalpy change in the evaporator ($h_1 - h_4$) decreased significantly when outdoor temperature increased, but the specific enthalpy change in the condenser ($h_2 - h_3$) changed much less compared to the evaporator.

Figure 4.4 shows the pressure-enthalpy (P-h) diagram for four tests at the same outdoor temperature of 27.8 °C (82.0 °F) and four different indoor conditions defined by the following set of indoor temperatures and relative humidity: 21.1 °C (70.0 °F)/50 %, 26.7 °C (80.0 °F)/50 %, 21.1 °C (70.0 °F)/dry-coil, and 26.7 °C (80.0 °F)/dry-coil (tests 4, 5, 12, and 13 of Table 3.2). Contrary to Figure 4.2, the specific enthalpy change in both the evaporator and condenser did not vary significantly between the different indoor operating conditions.

Figure 4.5 provides an overview of the variation of eight temperature measurements with regard to the outdoor chamber temperature. 'ID 21.1 °C (70.0 °F) DB', '50% RH', and 'Dry-coil' in the legend represent indoor air dry bulb temperature of 21.1 °C (70.0 °F), indoor relative humidity of 50 %, and an indoor dry-coil test with low relative humidity, respectively. Each line denotes different indoor conditions of dry-bulb temperature and relative humidity.

The first figure in the left-hand column shows that the evaporator saturation temperature for the wet-coil condition (50 % RH) is higher than that for the dry-coil condition. This is due to the moisture removal enhancing the air-side heat transfer coefficient, resulting in an evaporation temperature closer to the air

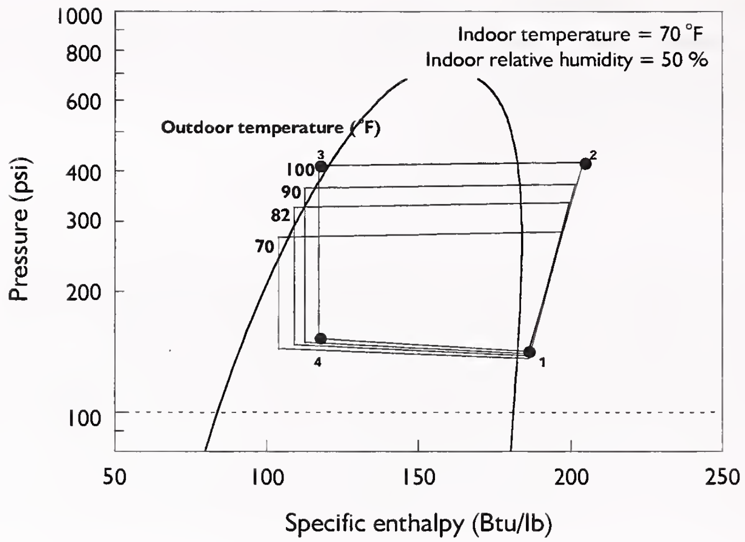


Figure 4.3. Pressure-enthalpy diagrams for tests at 37.8 °C (100.0 °F), 32.2 °C (90.0 °F), 27.8 °C (82.0 °F), and 21.1 °C (70.0°F) outdoor temperatures with 21.1 °C (70.0 °F) indoor temperature and 50 % relative humidity

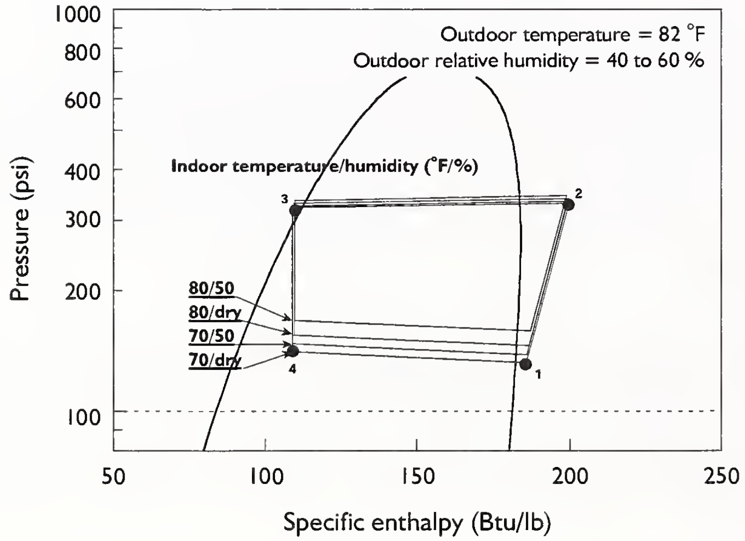


Figure 4.4. Pressure-enthalpy diagrams for tests at 27.8 °C (82.0 °F) outdoor temperature and four indoor temperature/relative humidity combinations: 26.7 °C (80.0 °F) DB/50 % RH, 26.7 °C (80.0 °F) DB/Dry-coil, 21.1 °C (70.0 °F) DB/50 % RH, 21.1 °C (70.0 °F) DB/Dry-coil

the second plot in the right-hand column. This figure also shows that the indoor conditions have a small influence on the condenser temperature.

The first figure in the right-hand side column of Figure 4.5 displays the variation of refrigerant superheat at the evaporator exit, ΔT_{sh}. As the plot shows, the degree of superheat increases at lower outdoor temperature. The figure also shows that the evaporator temperature increases as the outdoor temperature increases. This trend is even stronger for the condenser refrigerant saturation temperature, T_{CR}, shown in temperatures. This increase is particularly pronounced for the test with 26.7 °C (80.0 °F) dry-bulb temperature, where the TXV does not open wide enough to provide enough refrigerant flow at the small pressure differential between the evaporator and condenser. This observation is related to the increased subcooling, ΔT_{sc}, shown in the third figure of the left-hand column. Since the TXV does not open wide enough, the subcooling increases at low ambient temperatures.

The third figure in the right-hand column and the forth figure in the left-hand column, present the outdoor air temperature gain through the condenser, ΔT_{CA}, and the indoor air temperature drop through the evaporator, ΔT_{EA}, respectively. While the indoor air temperature change decreases for higher outdoor temperatures, the outdoor air gain remains at an approximately constant level.

The fourth plot in the right-hand column of Figure 4.5 shows the refrigerant temperature drop through the liquid line. As expected, liquid line temperature drop increases for a higher temperature difference between indoor and outdoor.

Figure 4.6 shows performance charts. All the points in the plots describe averaged measurements or residuals. The first three plots present the trends in the sensible capacity, latent capacity, and sensible heat ratio on the indoor air side. Sensible heat ratio is defined by the following equation:

$$\mathrm{SHR}_{\mathrm{EA}} = \frac{Q_{\mathrm{EA,sens}}}{Q_{\mathrm{EA}}} = \frac{Q_{\mathrm{EA,sens}}}{Q_{\mathrm{EA,sens}} + Q_{\mathrm{EA,lat}}} \tag{4.9}$$

Since there is no moisture removal during dry-coil tests, lines for 'ID 21.1 °C (70.0 °F) DB/Dry-coil' and 'ID 26.7 °C (80.0 °F) DB/Dry-coil' overlap on the plots for $Q_{\mathrm{EA,lat}}$ and sensible heat ratio.

Refrigerant mass flow rate, m_{R}, is little affected by the ambient temperature (second plot in the right-hand column). This is consistent with the results presented in Figure 4.4 showing that refrigerant states at the compressor suction are little changed with a change of the outdoor temperature condition. Although the compressor mass flow rate decreases with an increasing compression ratio (due to a degraded volumetric efficiency), in our case this trend must have been compensated for by a decrease in the suction superheat, which increases refrigerant density and mass flow rate pumped by the compressor.

On the contrary, the refrigerant mass flow rate is significantly influenced by a change of indoor conditions because this significantly affects the refrigerant state at the evaporator exit. When the evaporator temperature is reduced, vapor density at the compressor suction decreases and the mass flow rate also decreases.

The two plots in the third row of Figure 4.6 show the refrigerant-side capacities for the condenser and evaporator, Q_{CR} and Q_{ER}, respectively. The measurements show similar trends for both heat exchangers.

And finally, the plots in the bottom row show the compressor power and system EER. As the outdoor temperature increases, the compressor requires more power. However, the compressor power is a rather weak function of the indoor operating conditions; the lines representing compressor power for the four indoor conditions considered in this study nearly overlap each other. The EER plot shows some differences due to the differences in evaporator capacities.

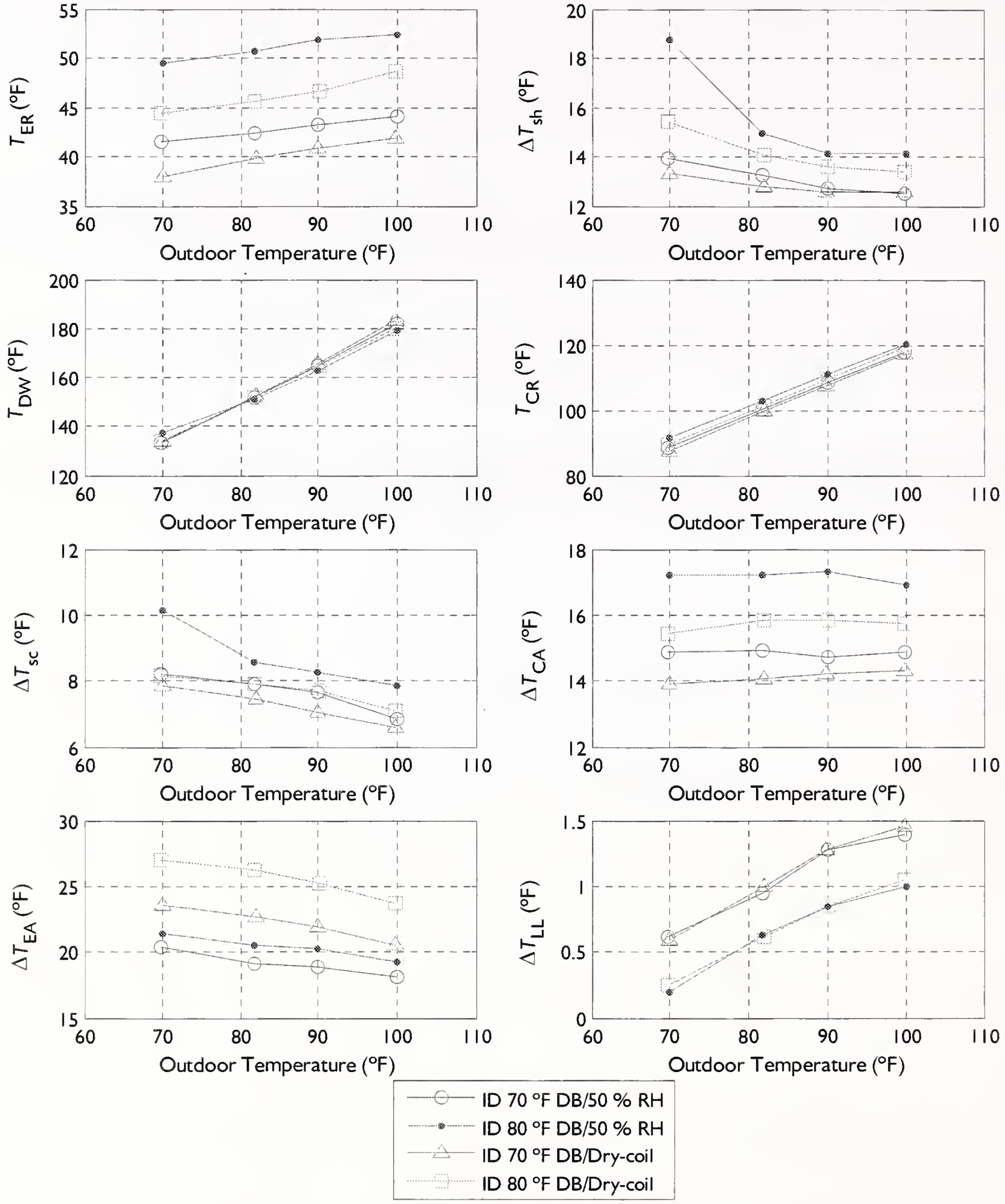


Figure 4.5. Variation of temperature measurements with regard to outdoor chamber temperature under no-fault condition: From the top left to right: T_{ER} – evaporator exit saturation temperature; ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, ΔT_{CA} - condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

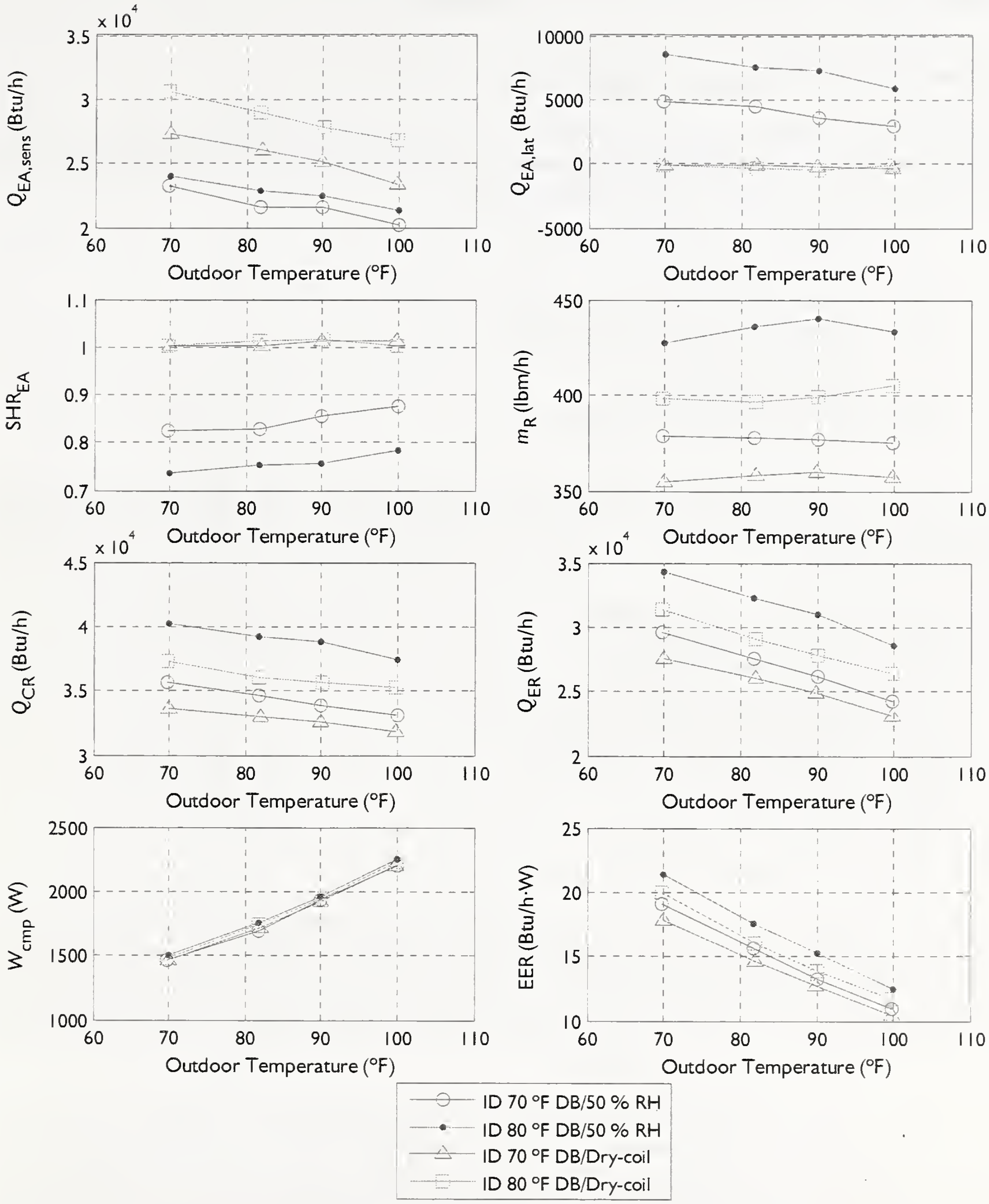


Figure 4.6. Variation of system performance with regard to outdoor air temperature under no-fault conditions: From the top left to right: $Q_{EA,sens}$ – indoor air sensible capacity, $Q_{EA,lat}$ – indoor air latent capacity, SHR_{EA} – indoor air sensible heat ratio, m_R – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{cmp} – compressor work, EER – energy efficiency ratio

CHAPTER 5. SINGLE-FAULT TEST RESULTS

5.1 Performance Variation under Single Faults

This section presents the results of single-fault tests. We tested the effect of individual faults at four operating conditions corresponding to the test index of 4, 5, 8, and 9 in Table 3.2. The subsections below present residuals, R(....), for the following eight features:

1. T_{ER} – evaporator exit saturation temperature
2. ΔT_{sh} – evaporator exit superheat
3. T_{DW} – compressor discharge wall temperature
4. T_{CR} – condenser inlet saturation temperature
5. ΔT_{sc} – liquid line subcooling
6. T_{CA} – condenser air temperature rise
7. ΔT_{EA} – evaporator air temperature drop
8. ΔT_{LL} – liquid line temperature drop.

We calculated each residual as a difference between the measured value and the value provided by the reference model for a given feature. In addition to the residuals, the results include the following performance parameters:

1. $Q_{EA,sens}$ – indoor air sensible capacity
2. $Q_{EA,lat}$ – indoor air latent capacity
3. SHR – indoor air sensible heat ratio
4. m_R – refrigerant mass flow rate
5. Q_{CR} – condenser refrigerant-side capacity
6. Q_{ER} – evaporator refrigerant-side capacity
7. W_{cmp} – compressor work
8. EER – energy efficiency ratio.

5.1.1 Compressor/reversing valve leakage

The compressor/reversing valve leakage fault involved at least three fault levels. The fault level was calculated as the ratio of refrigerant mass flow through the system with the fault imposed divided by the refrigerant mass flow rate during no-fault operation. Figure 5.1 shows the residuals described in Equation 4.8 for the eight selected features. The feature residuals in the plots were calculated based on the averaged measurements of fault tests and 2nd order no-fault polynomial model. Figure 5.2 shows the variations in averaged performance parameters.

From Figure 5.1, the refrigerant saturation temperature for the evaporator and condenser (T_{ER} and T_{CR}, respectively) show consistent responses for all four operating conditions. Also, the change in air temperature difference across the evaporator and condenser is similar for the operating conditions studied. This system characteristic corresponds to the similar slopes of the capacity lines for the evaporator and condenser presented in Figure 5.2. From the same figure, it is worth noticing that the refrigerant mass flow rate (m_R) and compressor power (W_{cmp}) are strongly affected by the outdoor temperature, while the indoor condition has a small influence on them. The compressor power slightly decreases with the increasing level of fault because of the corresponding reduction of the temperature (pressure) lift produced by the increased evaporator temperature and decreased condenser temperature. The EER is

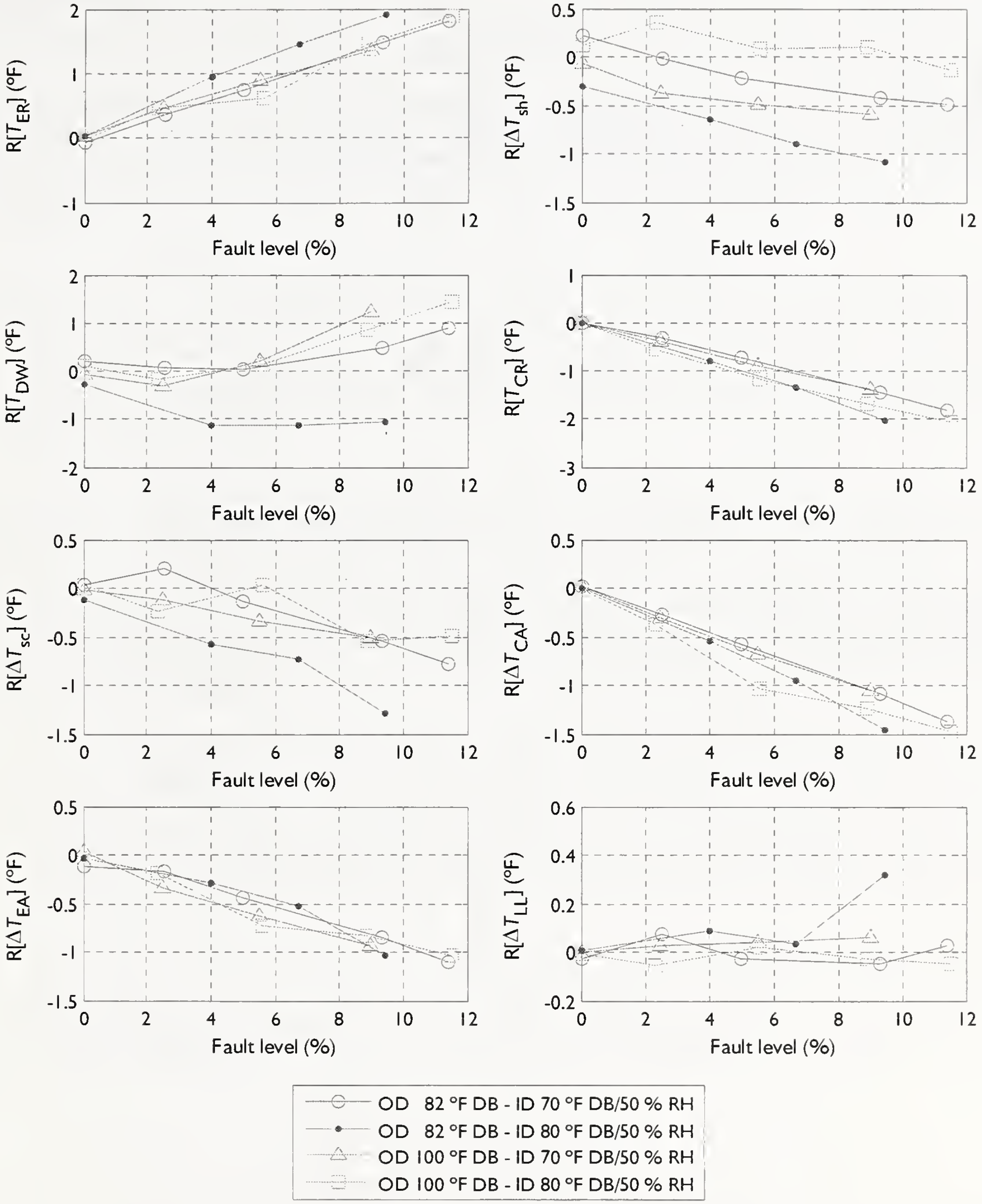


Figure 5.1. Residuals for selected feature with compressor fault. From the top left to right: T_{ER} – evaporator exit saturation temperature; ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

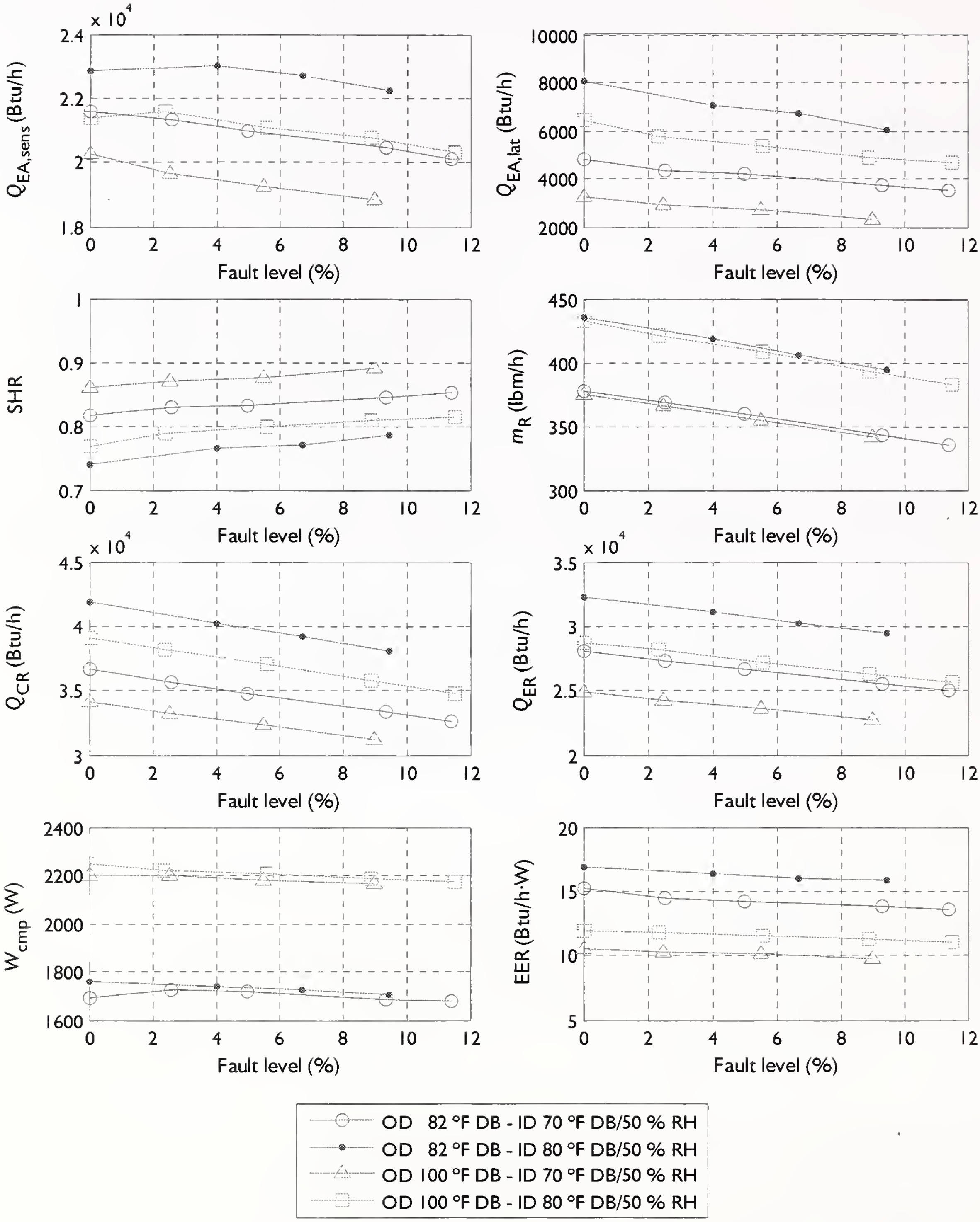


Figure 5.2. Variation of selected performance parameters with a compressor fault. From the top left to right: $Q_{\text{EA,sens}}$ – indoor air sensible capacity, $Q_{\text{AE,lat}}$ – indoor air latent capacity, SHR – indoor air sensible heat ratio, m_{R} – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity; Q_{ER} – evaporator refrigerant-side capacity; W_{comp} – compressor work; EER – energy efficiency ratio

degraded, however, because the reduction in the cooling capacity is greater than the reduction in the compressor power.

5.1.2 Improper outdoor coil air flow rate (condenser fouling)

We implemented fault levels of 5 %, 10 %, 20 %, 35 % and 50 % by blocking the corresponding percentage of the finned frontal area of the condenser. The fault level of 50 % was tested only for the operating conditions of 26.7 °C (80.0 °F) and 27.8 °C (82.0 °F) indoor and outdoor air temperatures, respectively, because of a concern of raising the condensing pressure too high and overloading the compressor.

Figure 5.3 shows residuals for the selected features, and Figure 5.4 shows variations of the performance parameters. Since condenser fouling is a fault occurring at a component level, its effect manifests itself most profoundly in condenser data. The change of evaporator temperature (T_{ER}) is minor, but the condenser temperature (T_{CR}) increases significantly for a higher condenser fouling level. The lines indicating the residuals overlap tightly showing so sensitivity the indoor and outdoor operating conditions (second plot in the right-hand side column). The compressor discharge temperature (T_{DW}) also increases with the increased level of fault.

All residuals "behave" in an expected, systematic fashion except those associated with the test at 26.7 °C (80.0 °F)/27.8 °C (82.0 °F) indoor/outdoor temperature at 35 % and 50 % fault levels. We speculate that during these two conditions, with greatly reduced condenser air flow, the refrigerant entering the TXV carried a substantial amount of bubbles, reducing the mass flow rate of refrigerant. Because of the amount of bubbles, the TXV could not allow sufficient refrigerant mass flow even if it were fully open. This condition is known as actuator saturation. The resulting reduction in refrigerant mass flow rate is shown in Figure 5.4 (second plot in the right-hand column) and is reflected also in the higher evaporator superheat shown in Figure 5.3.

The plot with the liquid line temperature change (ΔT_{LL}) provides an indication of the lack of refrigerant subcooling, or small subcooling, at the condenser outlet. Since the heat transfer between the liquid line and ambient is typically small, the temperature change in the liquid line is negligible unless two-phase refrigerant is entering the line or refrigerant flashes in the line due to its pressure drop. If the refrigerant is two-phase, the temperature decreases along the liquid line in proportion to the pressure drop. Most of the conditions with a fault level greater than 35 % show distinct temperature change in the liquid line.

Since the mass flow meter in the current investigation underestimates the value when the refrigerant is two-phase, all the performance parameters calculated from the refrigerant mass flow rate, i.e. condenser/evaporator refrigerant capacity, EER based on refrigerant capacity, etc., show excessive degradation at the specified conditions above. Compressor work increases with increasing fault level. In spite of the reduced refrigerant flow rate, increased condensing pressure requires additional compressor work.

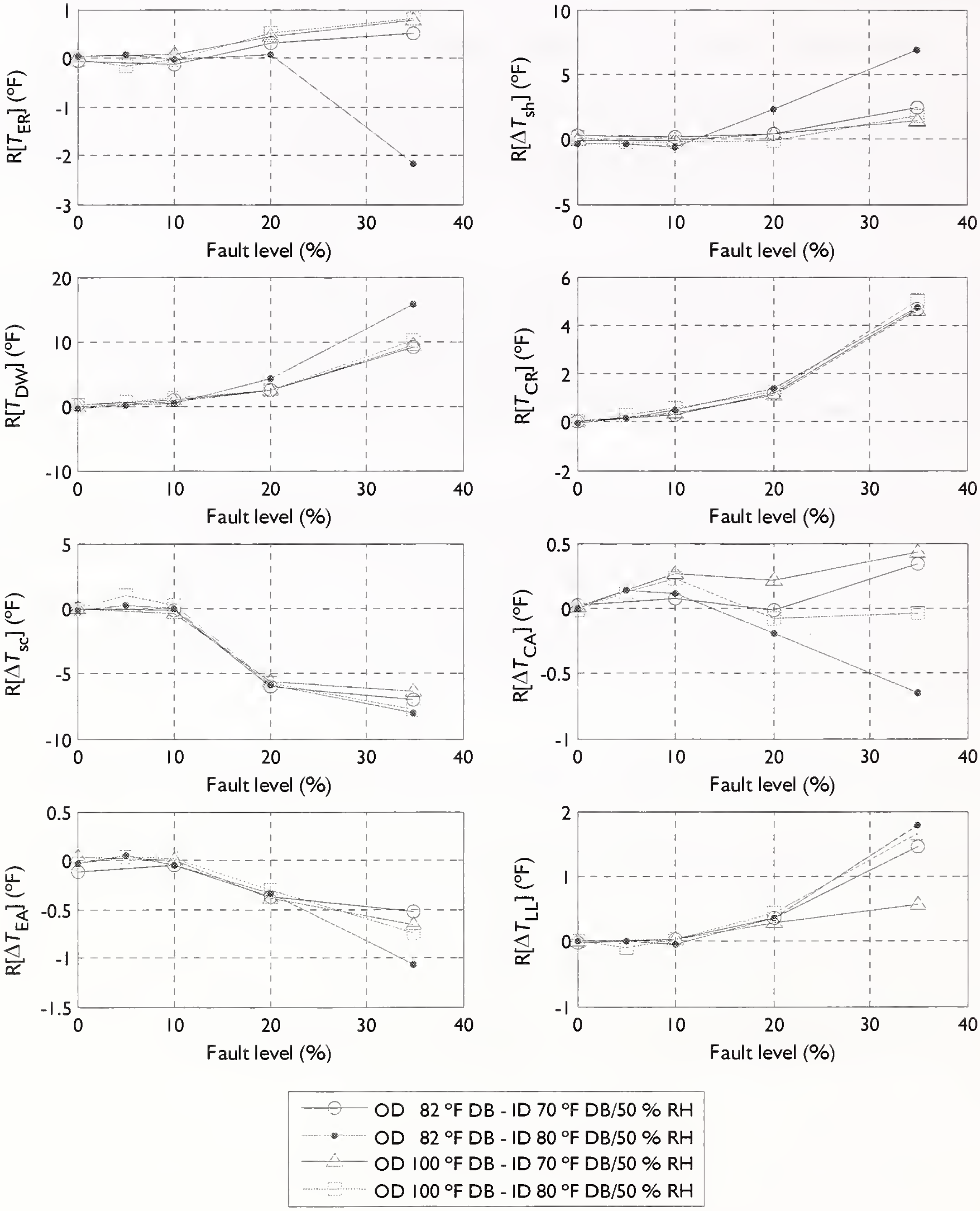


Figure 5.3. Residuals for selected features with the improper indoor air flow rate fault. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

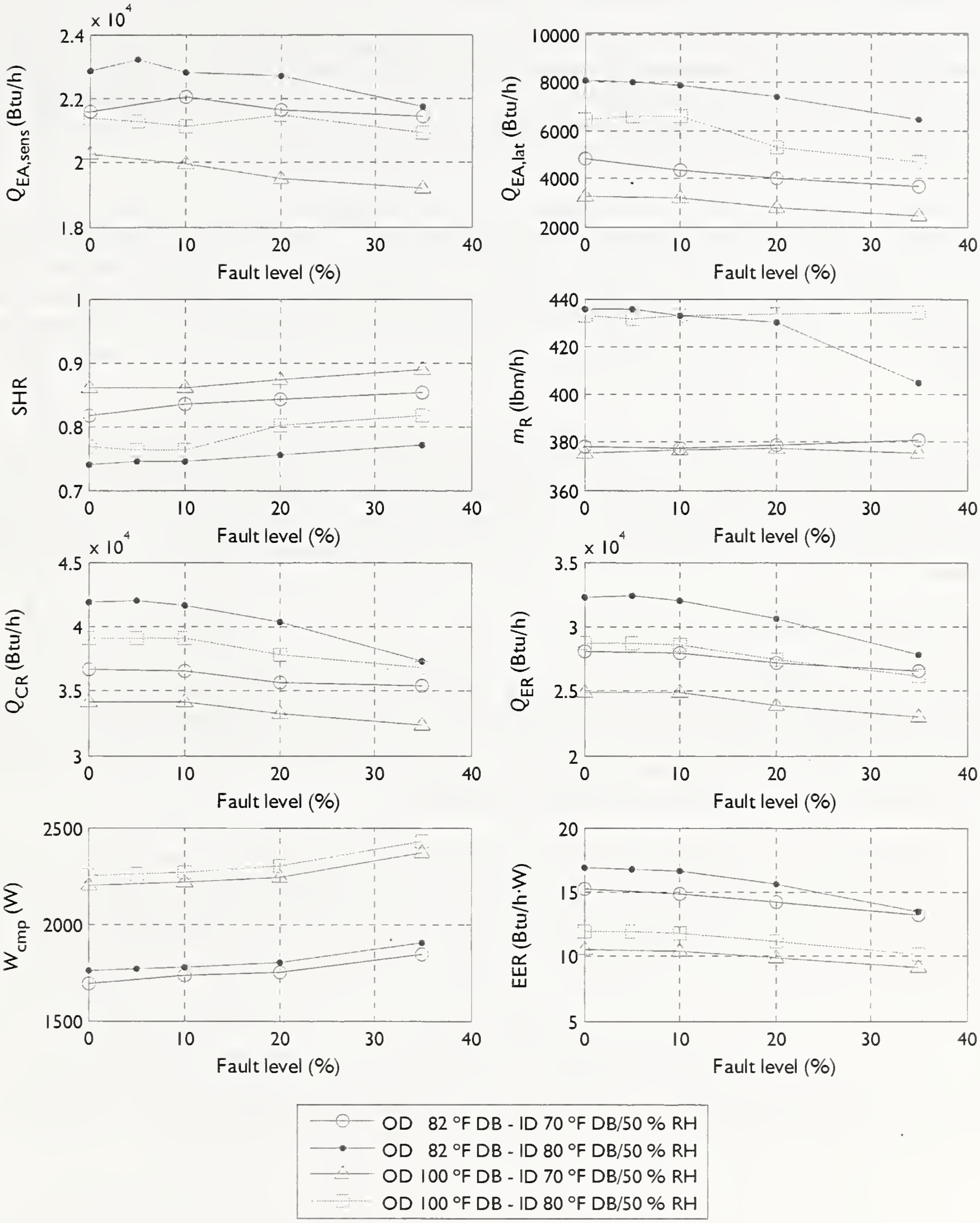


Figure 5.4. Variation of selected performance parameters with the improper indoor air flow rate fault. From the top left to right: $Q_{EA,sens}$ – indoor air sensible capacity, $Q_{AE,lat}$ – indoor air latent capacity, SHR – indoor air sensible heat ratio, m_R – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{comp} – compressor work, EER – energy efficiency ratio

5.1.3 Improper indoor air flow rate (evaporator fouling)

We implemented the improper indoor air flow rate fault by controlling the speed of the air fan located at the end of the ductwork. Reducing the indoor air flow approximates evaporator fouling. The tests included three fault levels at approximately 10 %, 20 %, and 30 %, which corresponded to the respective reductions of the air flow rate from the no-fault condition. Figure 5.5 shows residuals for the selected features, and Figure 5.6 shows variations of the performance parameters.

A change in the evaporator saturation temperature (T_{ER}) is the strongest indication of the reduced air flow. This change is very similar for all four operating conditions used. A change in the air temperature drop across the evaporator (ΔT_{EA}) is the second consistent system response for all operating conditions. The condenser saturation temperature also drops uniformly with the increased fault level; however, the temperature drop is only 0.6 °C (1.0 °F) for 30 % reduction in the indoor air flow. Also, the compressor discharge temperature (ΔT_{DW}) and liquid line temperature drop (ΔT_{LL}) show small changes in their residuals.

From Figure 5.6, both the sensible and latent capacity change linearly with reduced air flow. This is opposite of SHR trends seen for the compressor fault and condenser fouling fault, where the sensible heat ratio increased. The lowered evaporator temperature decreased the refrigerant density in the suction line causing a decrease in the refrigerant mass flow rate (m_{R}). However, the compressor work stays relatively constant throughout the fault tests because of the increased compression ratio. As expected, EER decreases.

5.1.4 Liquid line restriction

We implemented the restriction fault by modulating the settings of two valves installed in parallel in the liquid line. The level of the liquid line restriction fault was numerically assigned by the ratio of the increase in the liquid line pressure drop and the pressure differential between the upstream and downstream of the TXV at the no-fault condition. Figure 5.7 shows residuals for the selected features, and Figure 5.8 shows variations of the performance parameters.

In a system equipped with a variable opening expansion device – such as a TXV – the expansion device tends to compensate for over-restriction in the liquid line. Consequently, the over-restriction will not change the system performance as long as the expansion device can open enough to maintain refrigerant mass flow rate at the smaller available pressure differential that exists between the expansion device inlet and the inlet to the evaporator. In our case, the TVX was able to compensate for the restriction fault up to approximately a 10 % increase in liquid line pressure drop. Only after the restriction exceeded the 10 % fault level did the residuals for the selected features start to show a departure from their no-fault values. The fault was most pronounced for the evaporator superheat (ΔT_{sh}), evaporator saturation temperature, (T_{ER}), and the compressor discharge temperature (T_{DW}). All of the performance parameters plotted in Figure 5.8 were basically unaffected up to the 10 % fault level. Beyond this point, all performance parameters except the compressor work (W_{cmp}) and latent capacity ($Q_{\mathrm{EA,lat}}$) deteriorated.

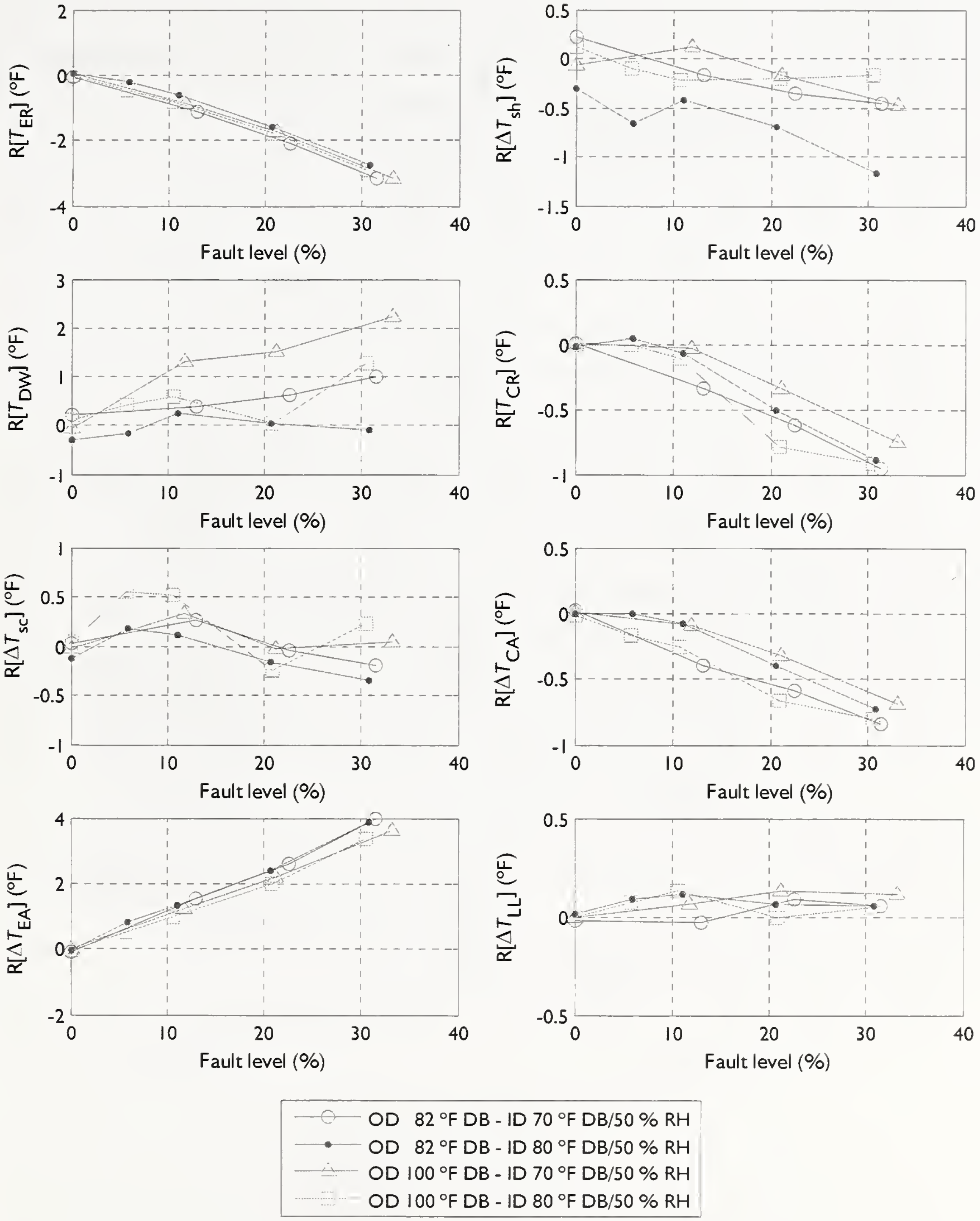


Figure 5.5. Residuals for selected features with the improper indoor air flow rate fault. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

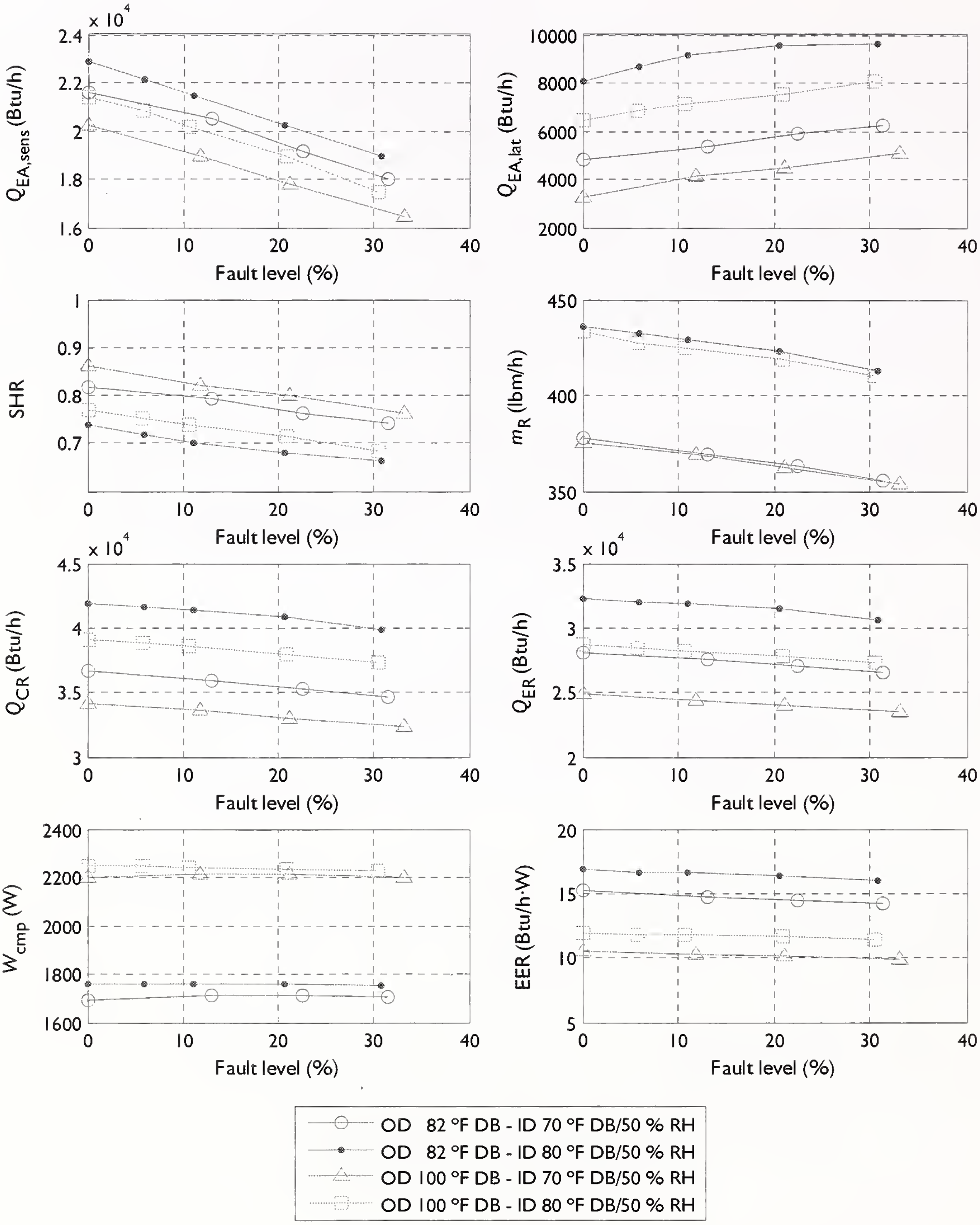


Figure 5.6. Selected performance parameters with the improper indoor air flow rate fault. From the top left to right: $Q_{\mathrm{EA,sens}}$ – indoor air sensible capacity, $Q_{\mathrm{AE,lat}}$ – indoor air latent capacity, SHR – indoor air sensible heat ratio, m_{R} – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{comp} – compressor work, EER – energy efficiency ratio

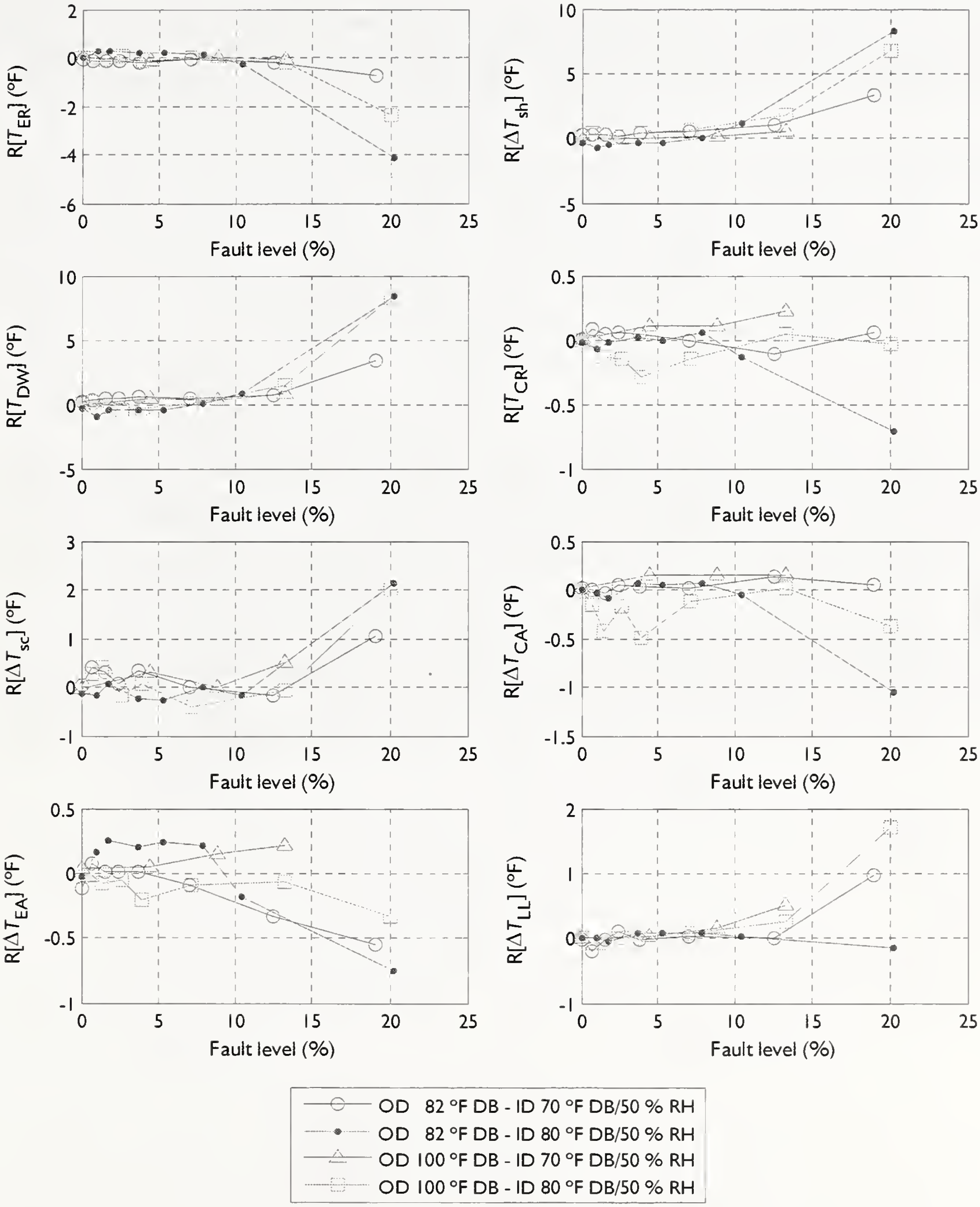


Figure 5.7. Residuals of selected features with the liquid line restriction fault. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

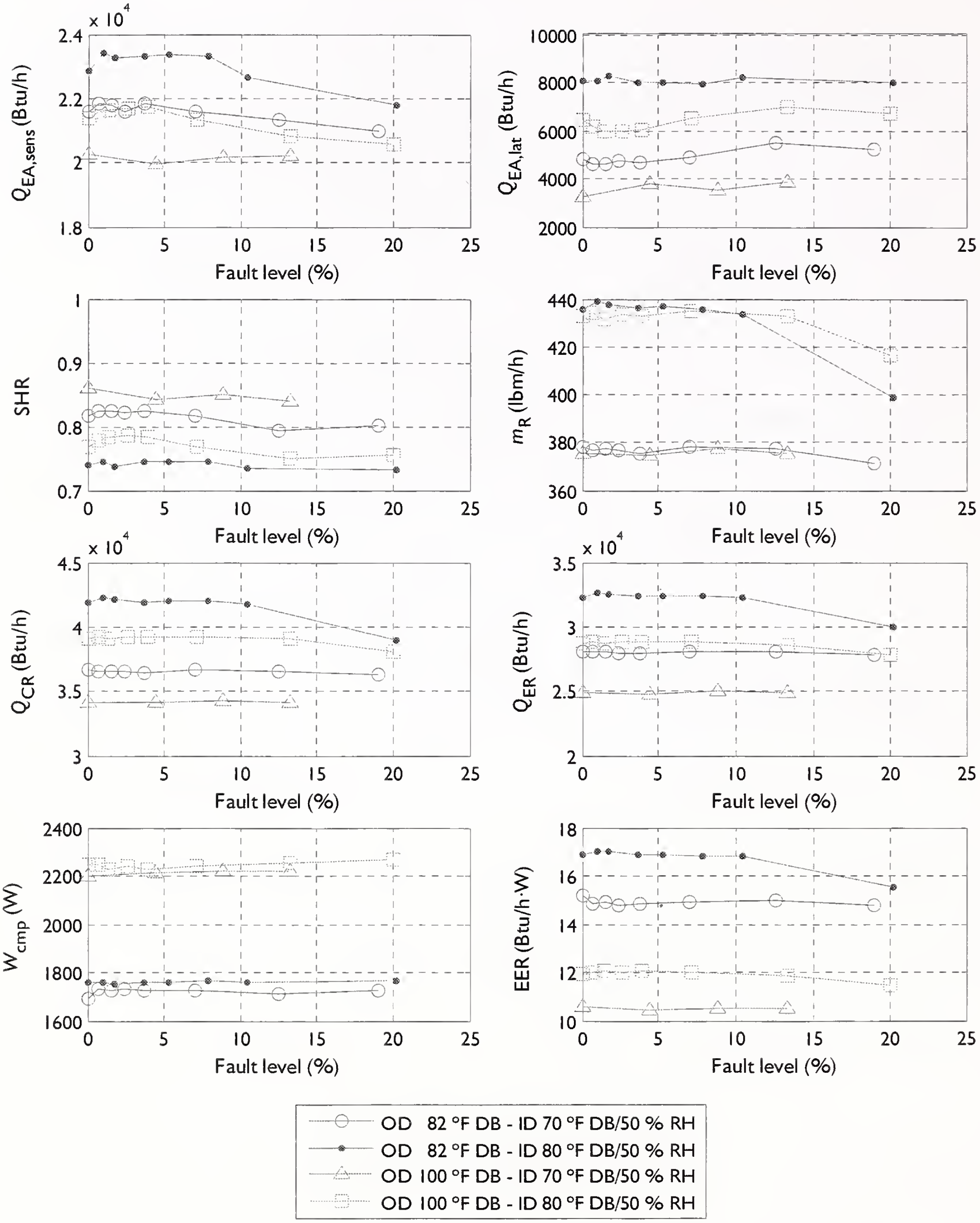


Figure 5.8. Selected performance parameters with the liquid line restriction fault. From the top left to right: $Q_{EA,sens}$ – indoor air sensible capacity, $Q_{AE,lat}$ – indoor air latent capacity, SHR – indoor air sensible heat ratio, m_R – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{comp} – compressor work, EER – energy efficiency ratio

5.1.5 Refrigerant undercharge and overcharge

The fault level for refrigerant undercharge (or refrigerant overcharge) was calculated as the ratio of the charge reduction (or charge excess) and the optimal refrigerant charge in the system. The test program included three fault levels: 10 %, 20 %, and 30 %. Figures 5.9 and 5.10 show residuals for the selected features for the undercharge and overcharge faults, respectively.

With an undercharge, the liquid line subcooling (ΔT_{sc}) is the most indicative of the fault starting at the 10 % fault level regardless of the operating conditions. The plot for liquid line temperature drop (ΔT_{LL}) provides a complementary indication, although its strength is influenced by the operating regime. As in previous cases, the liquid line temperature drop – if it is significant – is caused by a drop of the saturation temperature of the two-phase refrigerant flowing in the line. A reduced refrigerant charge causes the condenser temperature (T_{CR}) to decrease beginning at the 10 % fault; however, the rate of decrease varies somewhat with operating conditions. The compressor wall discharge temperature (T_{DW}), evaporator saturation temperature (T_{ER}), and evaporator superheat (ΔT_{sh}) provide non-linear signals with a strong dependence on operating conditions.

For the overcharging fault (Figure 5.10), the liquid line subcooling (ΔT_{sc}) and the condenser saturation temperature (ΔT_{sc}) increase steadily with the increasing refrigerant overcharge, and the plot for the four operating conditions almost overlap. The liquid line temperature drop (ΔT_{LL}) data indicate a decrease in the relative temperature drop and may provide a useful signal on the overcharge fault. The compressor wall discharge temperature (T_{DW}) decreases, but the strength of this trend varies somewhat between the tested cases. Other features do not provide a strong or consistent indication of refrigerant overcharging.

Figure 5.11 shows the variation of performance parameters for the undercharge and overcharge faults. Among the most important parameters, the evaporator capacity and compressor work increase with refrigerant charge level but at a different rate. Consequently, the EER plot has a maximum, which is reached at the optimal refrigerant charge in the system.

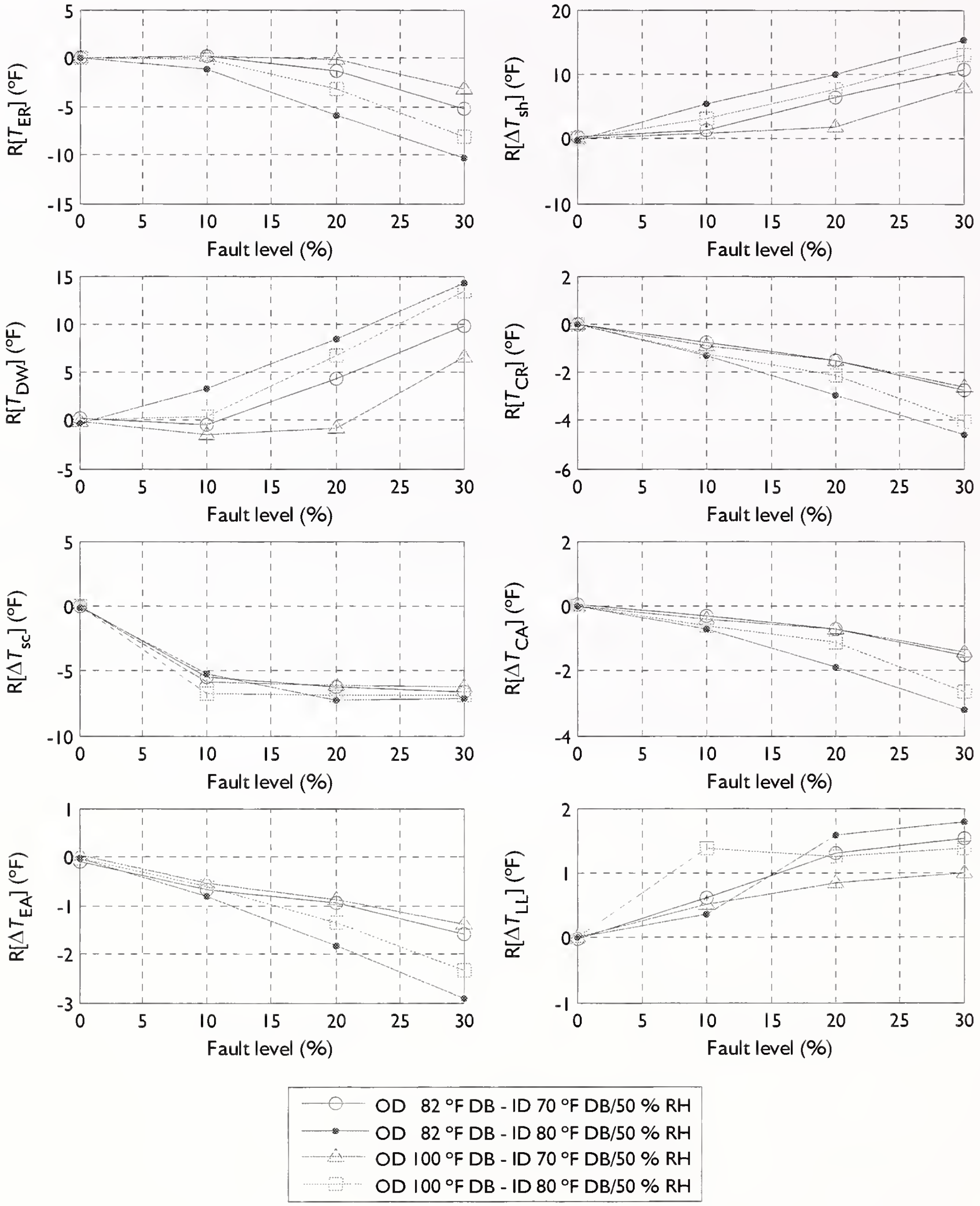


Figure 5.9. Residuals for selected features with refrigerant undercharge fault. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

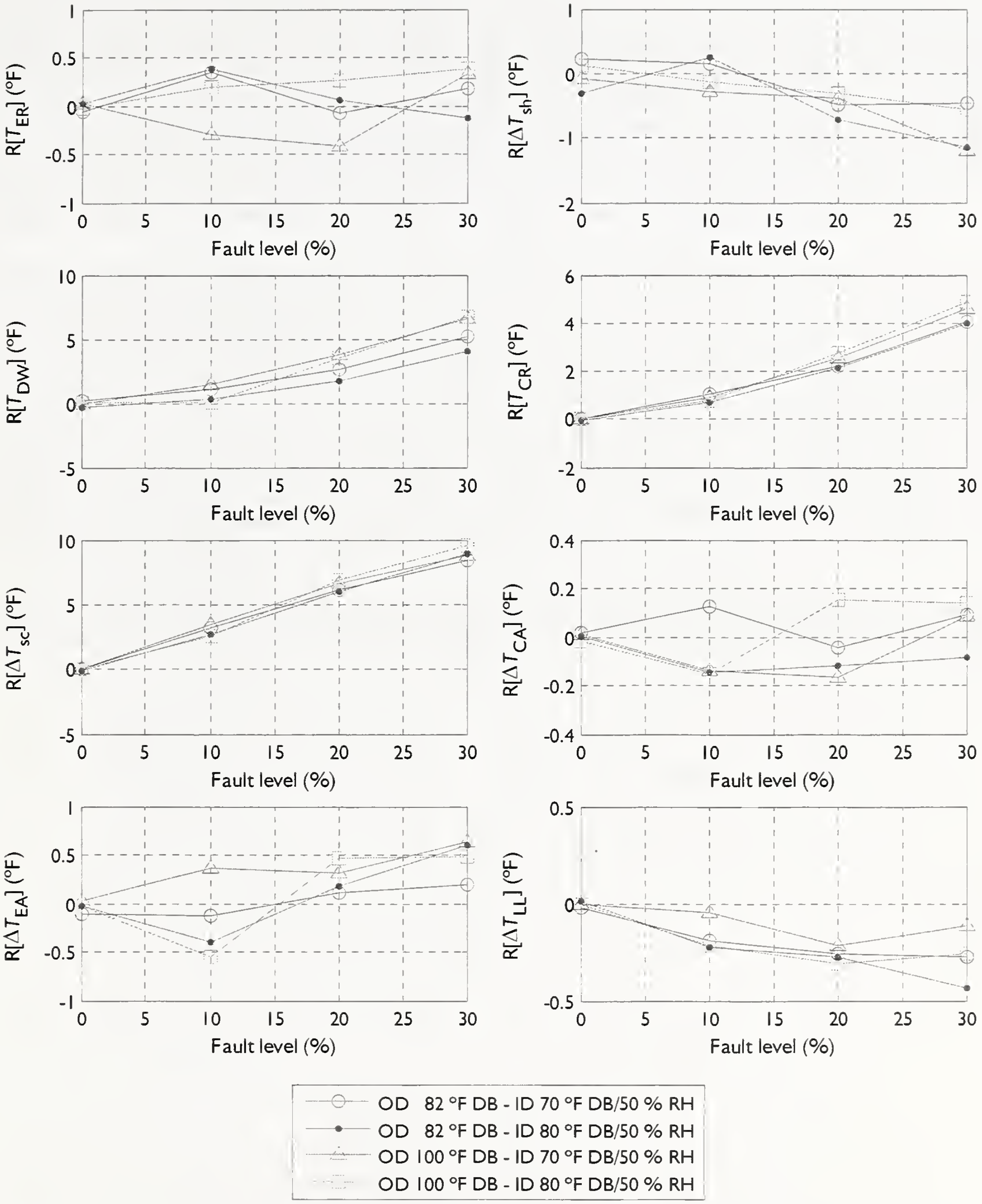


Figure 5.10. Residuals for selected features with refrigerant overcharge fault. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

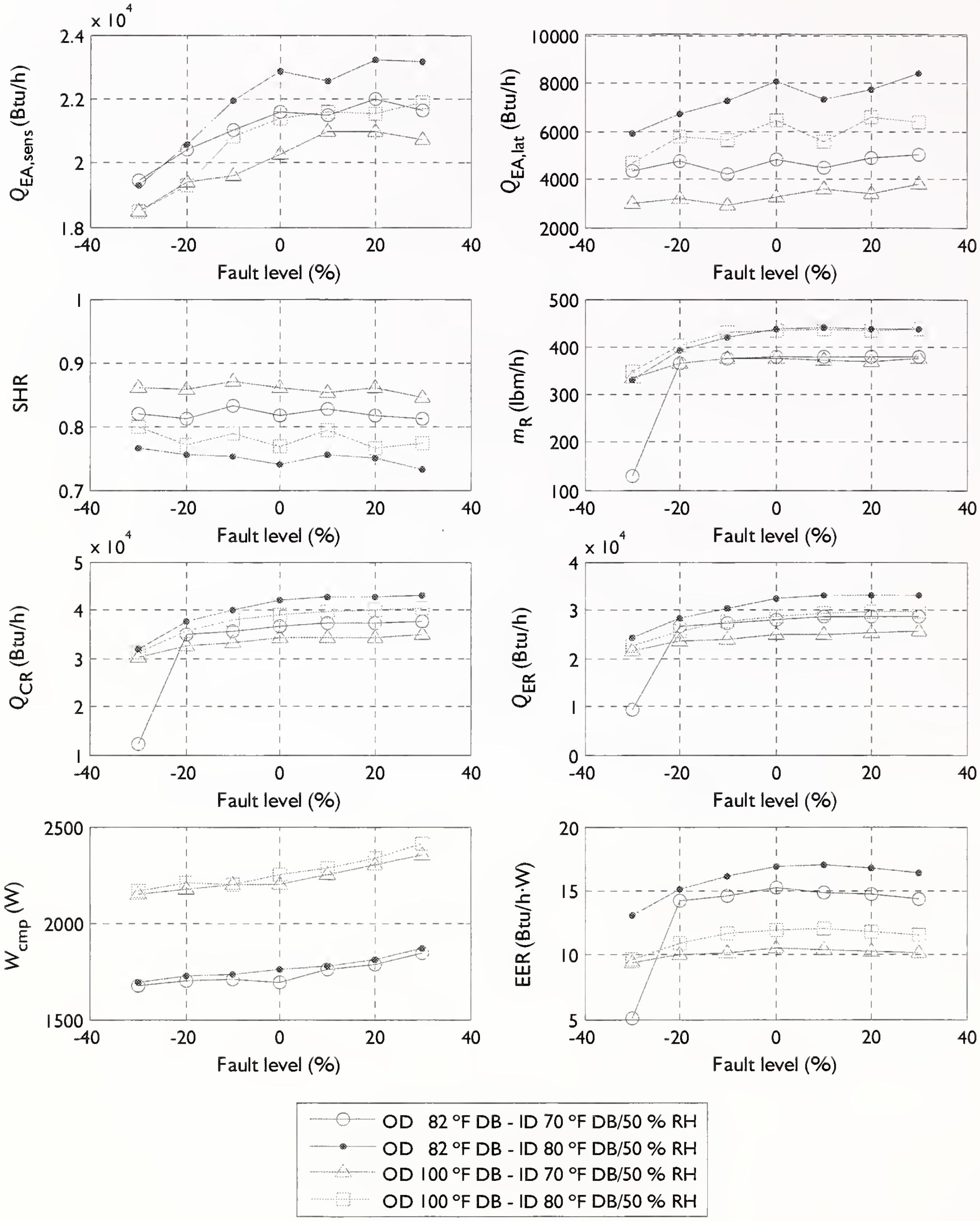


Figure 5.11. Selected performance parameters with respect to the refrigerant charge level. From the top left to right: $Q_{EA,sens}$ – indoor air sensible capacity, $Q_{AE,lat}$ – indoor air latent capacity, SHR – indoor air sensible heat ratio, m_R – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{comp} – compressor work, EER – energy efficiency ratio

5.1.6 Non-condensable gas

We implemented this fault by charging a controlled amount of dry nitrogen into the system. The mass of charged nitrogen divided by the mass of nitrogen that could occupy the system at atmospheric pressure indicated the fault level. We estimated that a typical level of this fault found in the field installation should not exceed 5 %, and for this level we performed tests for all four operating conditions applied to other faults. To include more severe scenarios, we carried out tests for 10 %, 15 %, and 20 % fault levels at two extreme operating conditions of outdoor 27.8 °C (82.0 °F) DB – indoor 26.7 °C (80.0 °F) DB/50 % RH and outdoor 37.8 °C (100.0 °F) DB – indoor 21.1 °C (70.0 °F) DB/50 % RH. Figure 5.12 shows residuals for the selected features, and Figure 5.13 shows variations of the performance parameters.

Among the features presented in Figure 5.12, the residuals for the liquid line subcooling (ΔT_{sc}) provide the strongest and most consistent indication of the increasing level of fault. Equally consistent is the plot for the condenser saturation temperature (T_{CR}) with a somewhat weaker sensitivity than that of ΔT_{sc}. The plot with the compressor discharge wall temperature (T_{DW}) also has a positive trend with the increasing level of fault; however, the collected data have a scatter that typically burdens compressor discharge temperature readings. All of the above features are related to the condenser, which can be explained by the fact that non-condensable gases are likely to accumulate in the condenser. Non-condensables collect on the high pressure side of the system and raise the condensing pressure above that corresponding to the temperature at which the refrigerant is actually condensing. This increases power consumption and reduces capacity. The excess pressure is caused by the partial pressure of the non-condensables. (ASHRAE Handbook – HVAC Systems and Equipment 35.6)

Performance parameter (Figure 5.13) changes are small. But due to the condenser pressure increase, the compressor work steadily increases and EER decreases with an increasing level of non-condensable.

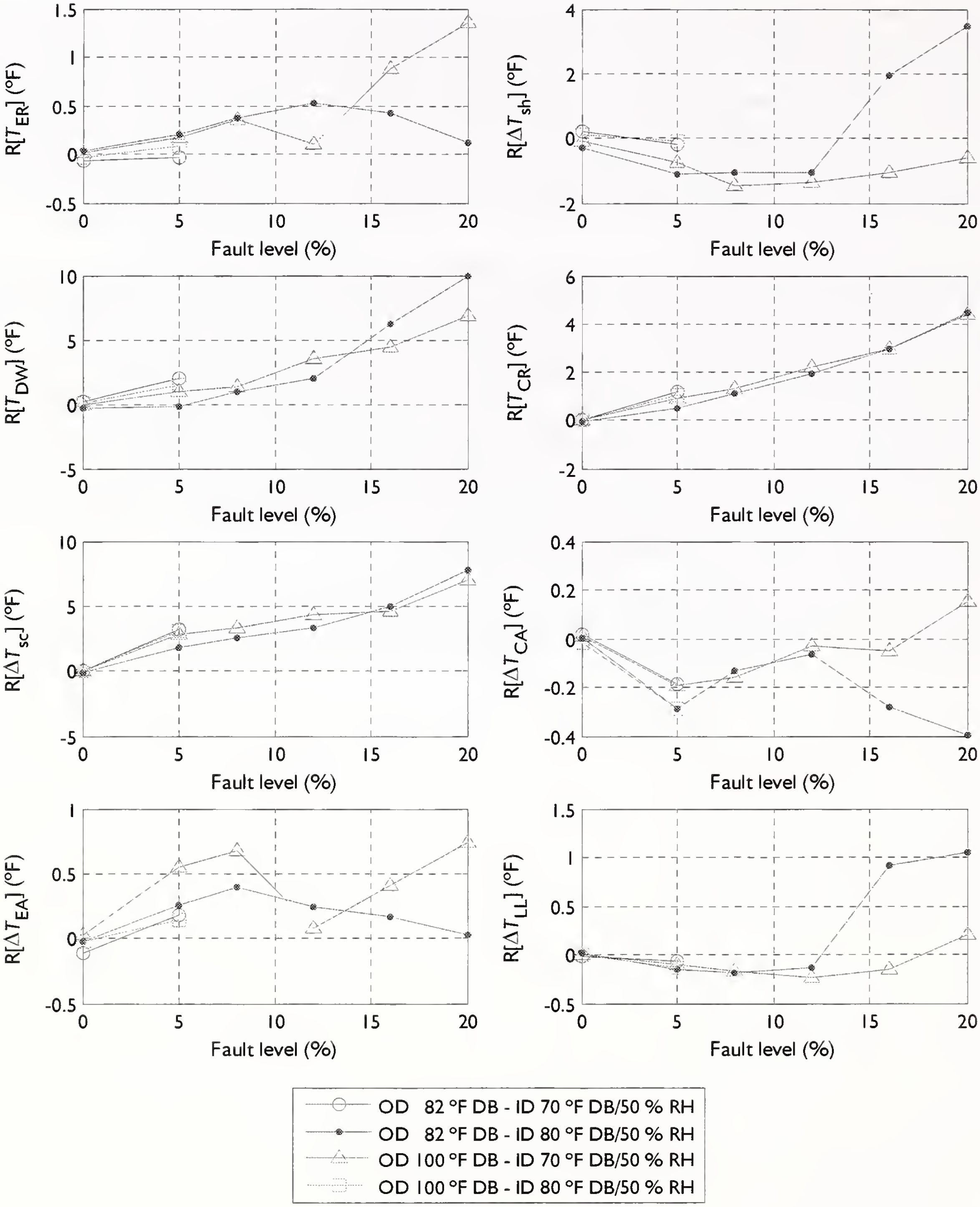


Figure 5.12. Residuals for selected features with non-condensable gas fault. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature, ΔT_{sc} – liquid line subcooling, T_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop

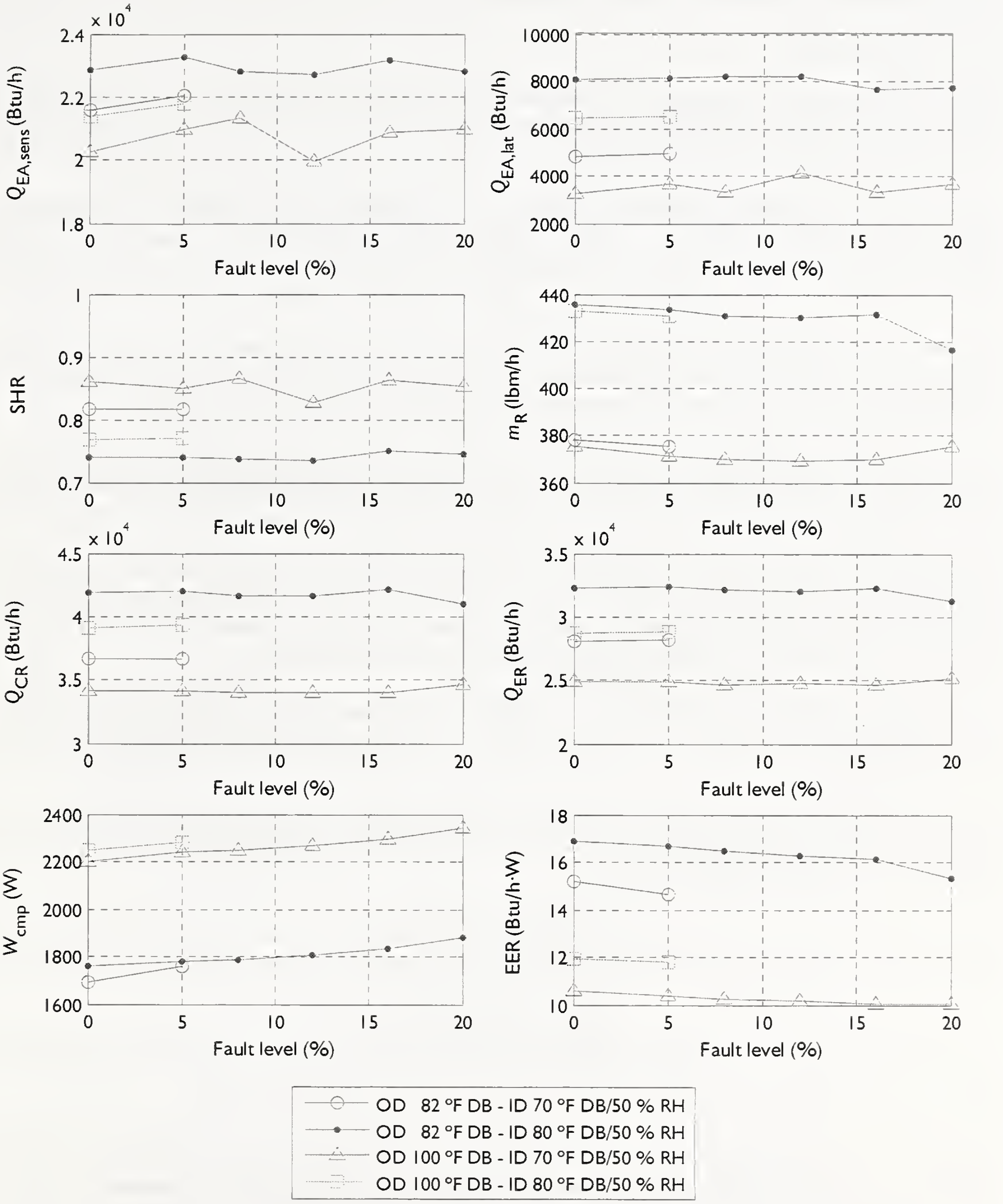


Figure 5.13. Selected performance parameters with non-condensable gas fault. From the top left to right: $Q_{EA,sens}$ – indoor air sensible capacity, $Q_{AE,lat}$ – indoor air latent capacity, SHR – indoor air sensible heat ratio, m_R – refrigerant mass flow rate, Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{comp} – compressor work, EER – energy efficiency ratio

5.2 Comparative Evaluation of Single-Fault Effects

5.2.1 Feature residuals

This section contains a comparative presentation of the effects of single faults on the eight selected features at 27.8 °C (82.0 °F) outdoor dry bulb temperature, 26.7 °C (80.0 °F) indoor dry bulb temperature, and 50 % indoor relative humidity (Test #5).

The evaporator saturation temperature (T_{ER}, Figure 5.14) is affected most by refrigerant undercharge and liquid line restriction yielding a negative residual. Other faults have a small impact except compressor/reversing valve leakage, which results in a 1.1 °C (2.0 °F) positive T_{ER} residual for 10 % level fault.

The suction line superheat (ΔT_{sh}, Figure 5.14) is affected most by refrigerant undercharge, liquid line restriction, non-condensable gases, and improper outdoor air flow rate. The $\mathrm{R}(\Delta T_{\mathrm{sh}})$ chart shows that the TXV was able to properly control refrigerant superheat for when other faults were applied.

The compressor discharge wall temperature (T_{DW}, Figure 5.14) feature has significant positive residuals for refrigerant undercharge, non-condensable gases, liquid line restriction, and improper outdoor air flow rate, and it has a moderate positive residual for refrigerant overcharge. Other faults have a minimal effect.

The condenser inlet saturation temperature (T_{CR}, Figure 5.14) is minimally affected by refrigerant overcharge, and liquid line restriction. Positive residuals for this residual were obtained for non-condensable gases, refrigerant overcharge, and low outdoor air flow rate; while negative residuals were calculated for compressor/reversing valve leakage and refrigerant undercharge.

The residuals of liquid line subcooling (ΔT_{sc}, Figure 5.15) are large enough for FDD methods for non-condensable gases and refrigerant overcharge (positive), and refrigerant undercharge and low outdoor air flow rate (negative).

The condenser air temperature gain (ΔT_{CA}, Figure 5.15) is negatively affected by each fault; however, the residuals are small in general, and only refrigerant undercharge and possibly compressor/reversing valve leakage could be detected using this feature.

The evaporator air temperature drop (ΔT_{EA}, Figure 5.15) residuals are suitable for FDD methods for low indoor air flow rate (positive) and refrigerant undercharge (negative). Other residuals are within 0.6 °C (1.0 °F) for the faults studied.

The liquid line temperature drop (ΔT_{LL}, Figure 5.15) has residuals within 1.1 °C (2.0 °F) for all studied faults offering limited opportunity for fault detection. The most influential faults for this feature are refrigerant undercharge, non-condensable gases, and improper outdoor air flow rate.

Figures 5.16 and 5.17 compare the impact of different single faults on performance parameters shown as residuals. The reference values of performance parameters were calculated by the 2nd order multivariate polynomial described in section 4.3. The sensible capacity ($Q_{\mathrm{EA,sens}}$, Figure 5.16) decreased for all faults except refrigerant overcharge for which capacity was rather steady, and the latent capacity ($Q_{\mathrm{EA,lat}}$, Figure 5.16) decreased for all faults except low indoor air flow for which latent capacity increased.

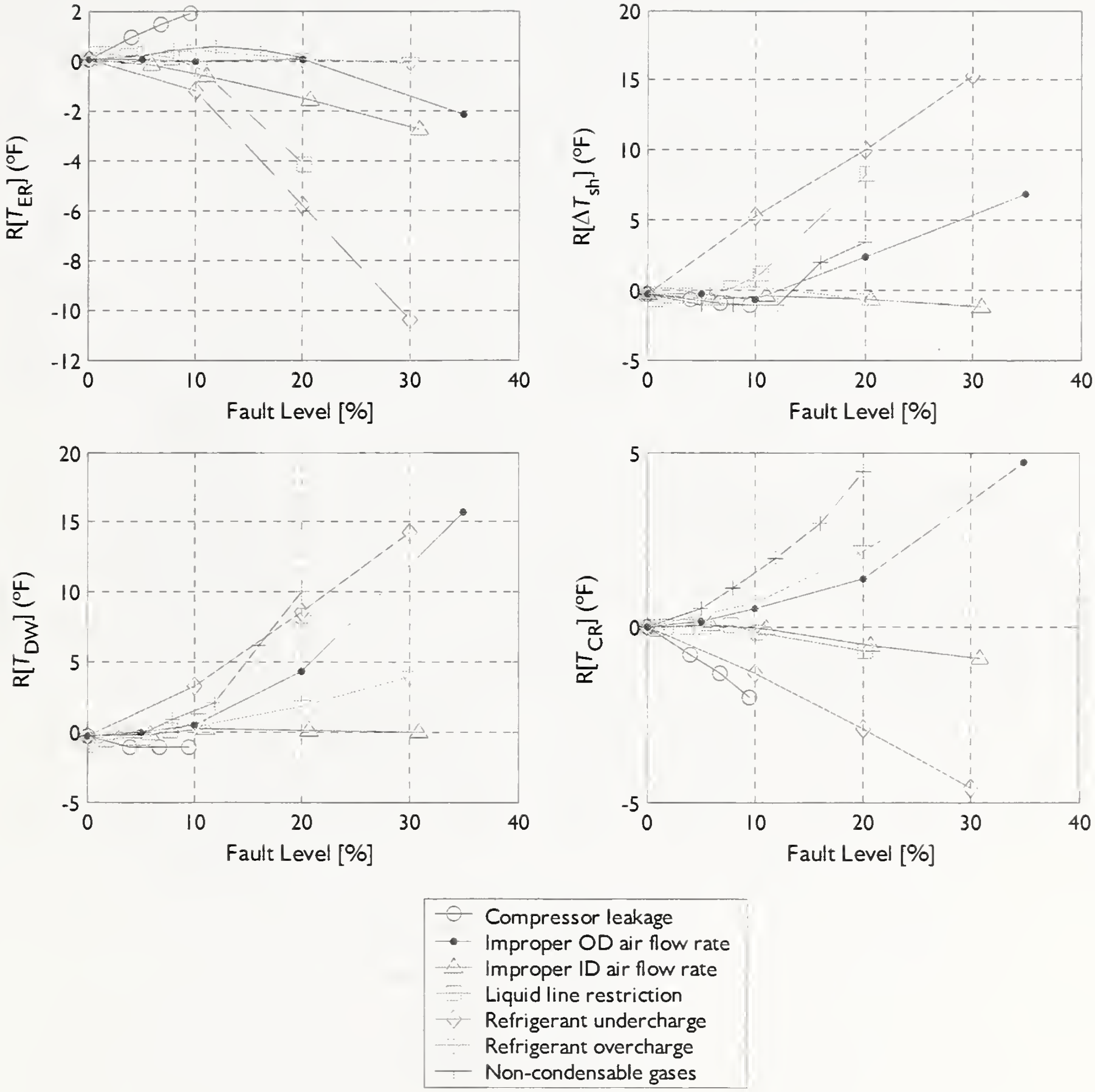


Figure 5.14. Residuals for selected features for different faults. From the top left to right: T_{ER} – evaporator exit saturation temperature, ΔT_{sh} – evaporator exit superheat, T_{DW} – compressor discharge wall temperature, T_{CR} – condenser inlet saturation temperature
(Test #5: 27.8 °C (82.0 °F) outdoor dry bulb temperature, 26.7 °C (80.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)

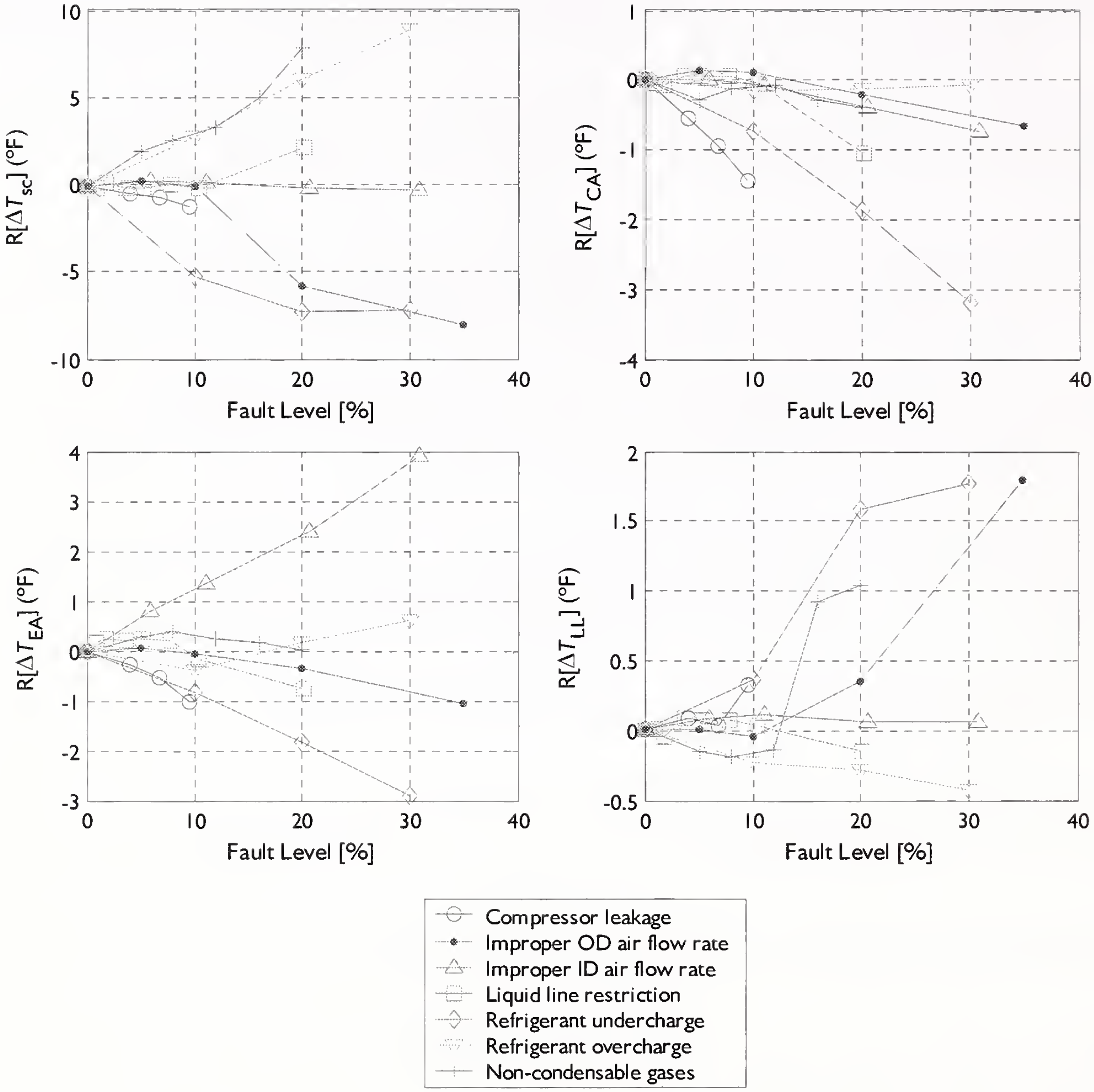


Figure 5.15. Residuals for selected features for different faults. From the top left to right: ΔT_{sc} – liquid line subcooling, ΔT_{CA} – condenser air temperature rise, ΔT_{EA} – evaporator air temperature drop, ΔT_{LL} – liquid line temperature drop
(Test #5: 27.8 °C (82.0 °F) outdoor dry bulb temperature, 26.7 °C (80.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)

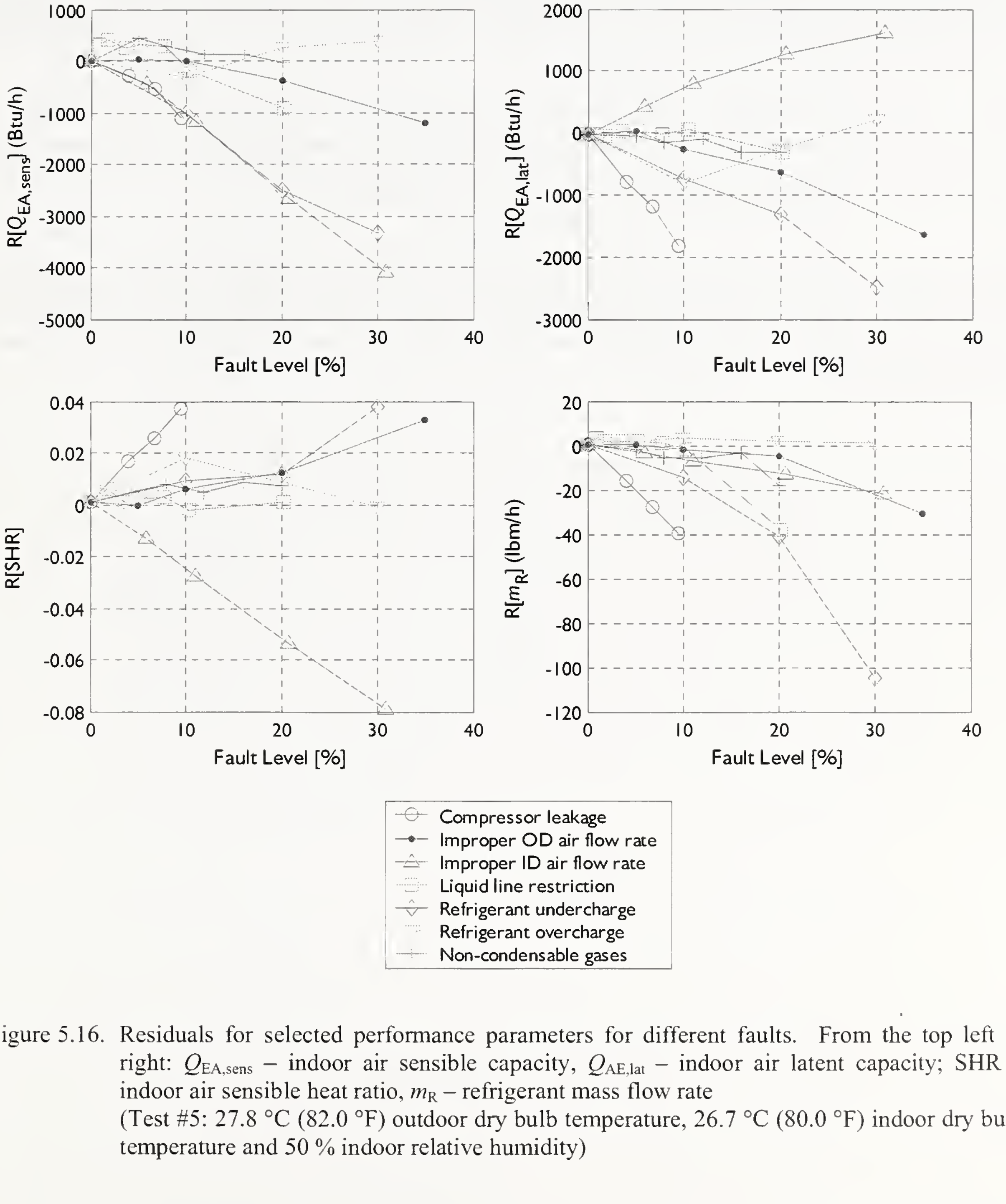


Figure 5.16. Residuals for selected performance parameters for different faults. From the top left to right: $Q_{\text{EA,sens}}$ – indoor air sensible capacity, $Q_{\text{AE,lat}}$ – indoor air latent capacity; SHR – indoor air sensible heat ratio, m_{R} – refrigerant mass flow rate (Test #5: 27.8 °C (82.0 °F) outdoor dry bulb temperature, 26.7 °C (80.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)

The refrigerant mass flow rate (m_R, Figure 5.16) was unchanged for refrigerant overcharge, but decreased markedly for all other faults.

As expected, condenser capacity (Q_{CR}, Figure 5.17) and evaporator capacity (Q_{ER}, Figure 5.17) decreased for each fault except refrigerant overcharge. The compressor work (W_{cmp}, Figure 5.17) increased for non-condensable gases, refrigerant overcharge, and low outdoor air flow rate; and it did not change or decreased for the remaining faults. The consequence of these changes in Q_{ER} and W_{cmp} is a degraded EER for each fault (Figure 5.17).

Even though the performance degradation due to refrigerant overcharge is not large, refrigerant overcharge may cause a serious problem, especially for a heat pump system. During winter, the refrigerant usually floods the evaporator. In the overcharge system, this flooding will be more severe and may results in liquid refrigerant entering the compressor and damaging it.

We may note that the sensitivity of residuals to a fault level depends on the system design. For example, heat exchanger faults will generally have a smaller effect on different residuals if heat exchangers are oversized. Or, the refrigerant overcharge fault is less apparent in systems equipped with a suitable liquid line receiver. Even the non-condensable gases fault can be mitigated by a large receiver since non-condensables tend to accumulate in it.

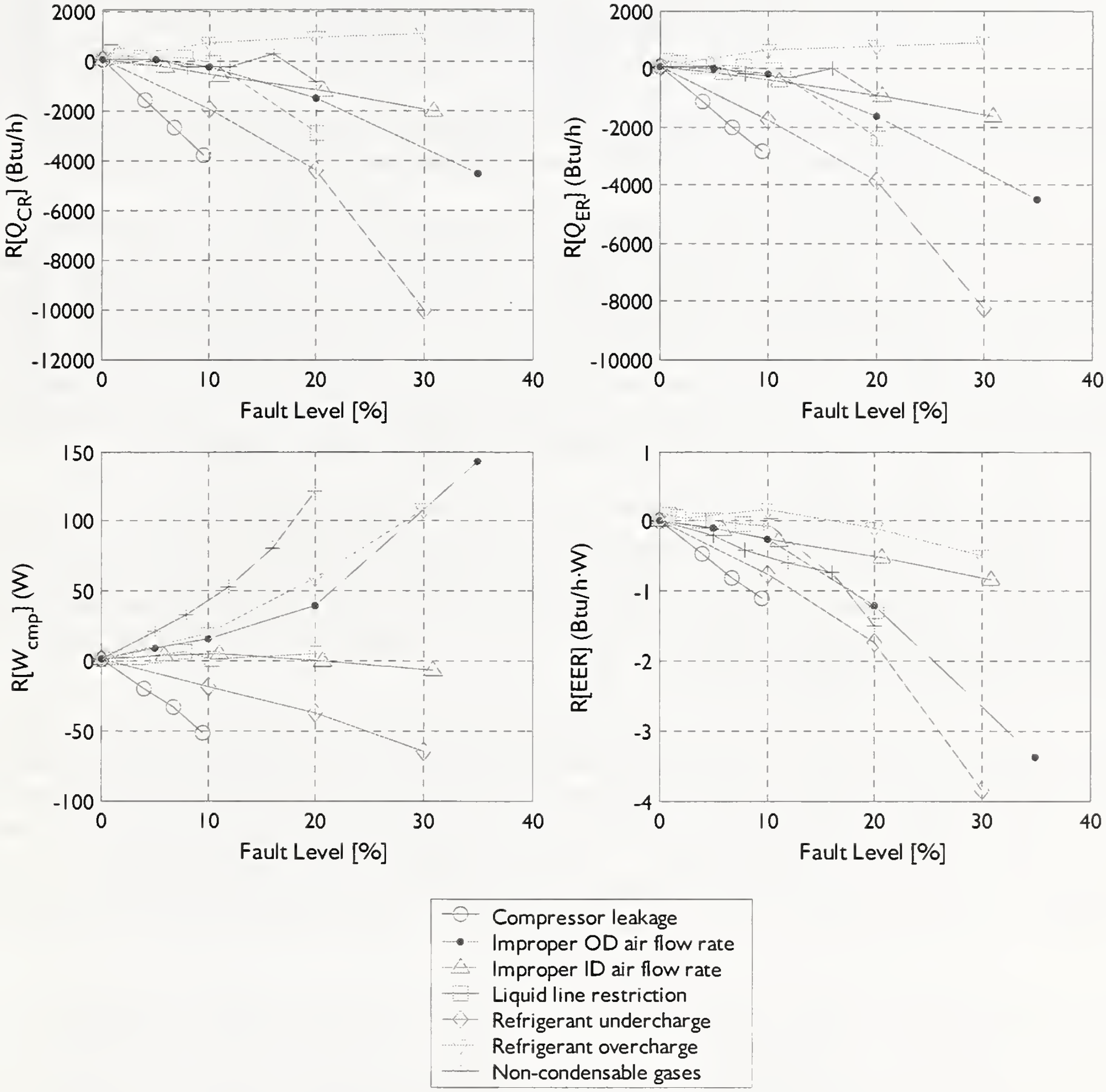


Figure 5.17. Residuals for selected performance parameters for different faults. From the top left to right: Q_{CR} – condenser refrigerant-side capacity, Q_{ER} – evaporator refrigerant-side capacity, W_{comp} – compressor work, EER – energy efficiency ratio

(Test #5: 27.8 °C (82.0 °F) outdoor dry bulb temperature, 26.7 °C (80.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)

5.2.2 Performance variations

Figures 5.18 to 5.25 present percent variations of performance parameters $\mathrm{R}^*(\phi_i)$ for different single-fault experiments and four operating conditions, where:

$$\mathrm{R}^*(\phi_i) = \frac{\phi_{i,\text{measurements}} - \phi_{i,\text{reference}}}{\phi_{i,\text{reference}}} = \frac{\mathrm{R}(\phi_i)}{\phi_{i,\text{reference}}} \tag{5.1}$$

Variation of residuals is denoted by the subscript which abbreviates the corresponding fault in Table 3.1. Reference values were obtained from 2nd order multivariate polynomial models described in Section 4.3.

Figures 5.18 and 5.19 show the variation of evaporator sensible capacity ($Q_{\mathrm{EA,sens}}$) and latent capacity ($Q_{\mathrm{EA,lat}}$). The sensible capacity is most significantly degraded by low indoor air flow, refrigerant undercharge, and compressor fault. The latent capacity is degraded by the compressor fault, low outdoor air flow rate, but is increased at the low indoor air flow rate. This increase of latent capacity can be explained by a decreased air velocity allowing for longer contact between the air and the evaporator surface. The changes in the sensible and latent capacities are reflected in changes in the indoor air sensible heat ratio (SHR) shown in Figure 5.20. Sensible heat ratio increases as the latent capacity decreases since the faults degrade moisture condensation performance for the evaporator.

Refrigerant mass flow rate (m_{R}) is most affected by the compressor fault and low indoor air flow (Figure 5.21). The same two faults affect the condenser capacity (Q_{CR}) and evaporator capacity (Q_{ER}) which starts its degrading influence at the 10 % fault level of reduced air flow (Figures 5.22 and 5.23, respectively). Compressor work (W_{cmp}) is increased with increasing fault levels for non-condensable gases, refrigerant overcharge, low outdoor air flow rate, and is decreased somewhat with the compressor fault and refrigerant undercharge (Figure 5.24).

Figures 5.22 and 5.23 show the condenser refrigerant capacity (Q_{CR}) and evaporator refrigerant capacity (Q_{ER}), respectively. Each capacity is calculated based on the refrigerant flow rate and the local enthalpies at the inlet and exit of the heat exchanger. Condenser exit enthalpy was used as evaporator inlet enthalpy as it was. In case that the refrigerant in condenser exit is in two phase, the local enthalpy was calculated based on the assumption of a saturated liquid. Both of heat capacities were changed similarly with the previous performance parameters, but they increases uniquely for refrigerant overcharge fault. It means refrigerant overcharge fault does give a benefit in capacity. However, EER will be decreased since compressor work is increased more than the capacity benefit.

Figure 5.25 shows the variation of energy efficiency ratio (EER). As expected, EER is decreased in all fault experiments. In cases of refrigerant overcharge and liquid line restriction, EER is relatively robust to fault level. EER shows no change at a low level of liquid line restriction fault. Since the TXV can control the suction line superheat close to its preset value, EER degradation appears only at a high fault level when the subcooled liquid refrigerant is flashed into two phase near the TXV. With the refrigerant overcharge fault, the increase of evaporator capacity can partially compensate compressor work. Thus only slight EER degradation is observed. However, the refrigerant overcharge fault should be monitored carefully since it can lead to compressor damage.

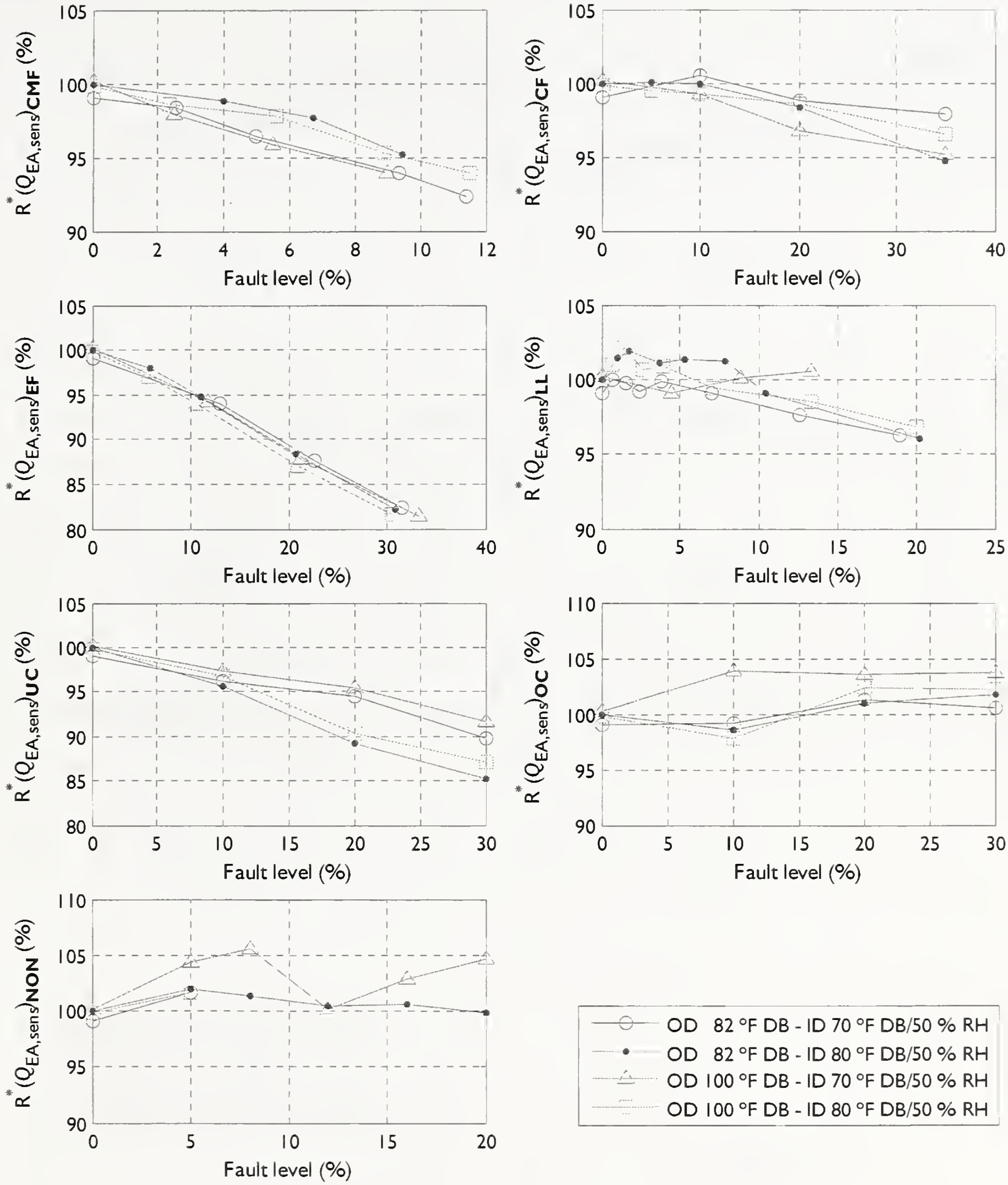


Figure 5.18. Variation of evaporator sensible capacity ($Q_{EA,sens}$) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

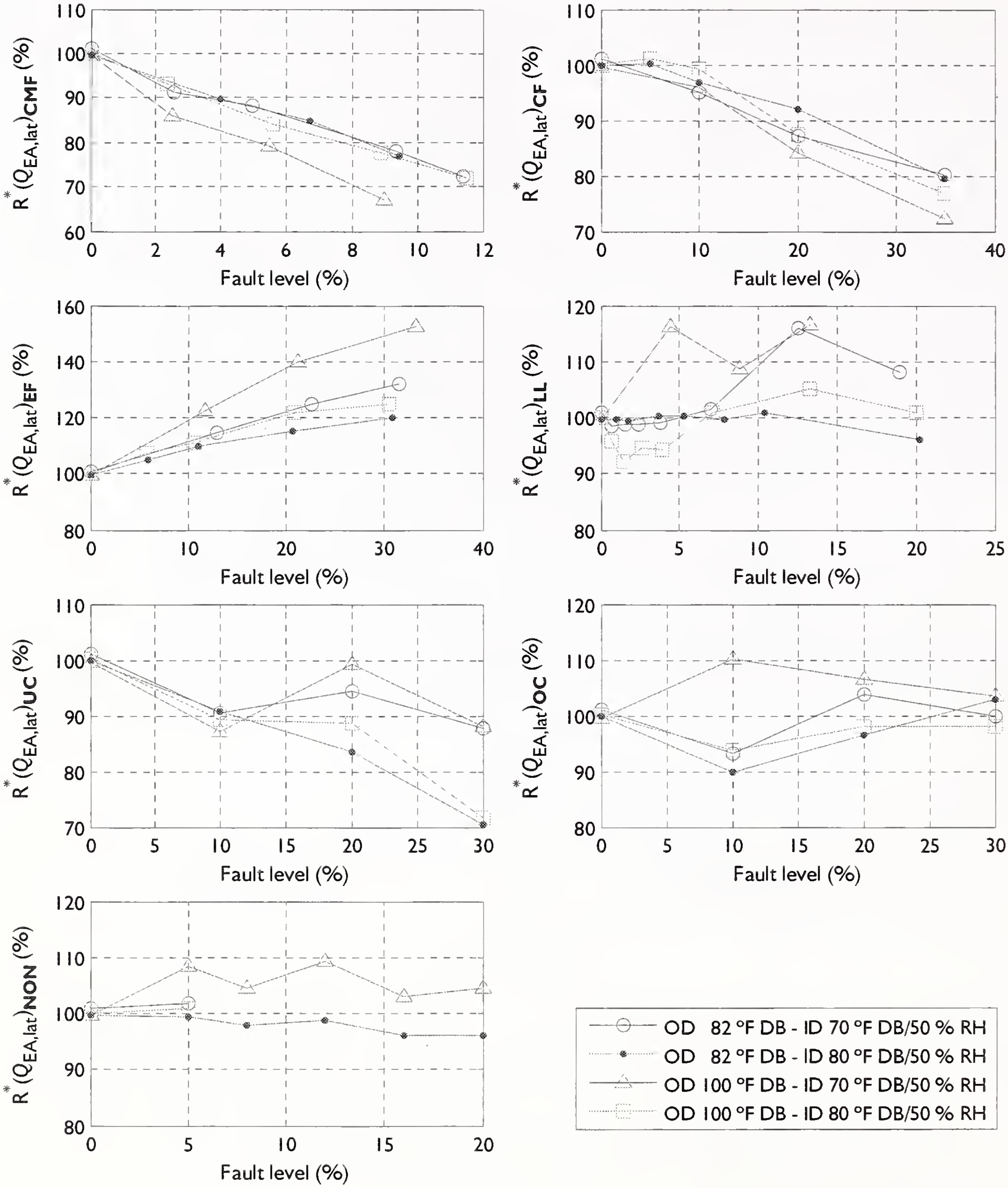


Figure 5.19. Variation of evaporator latent capacity ($Q_{EA,lat}$) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

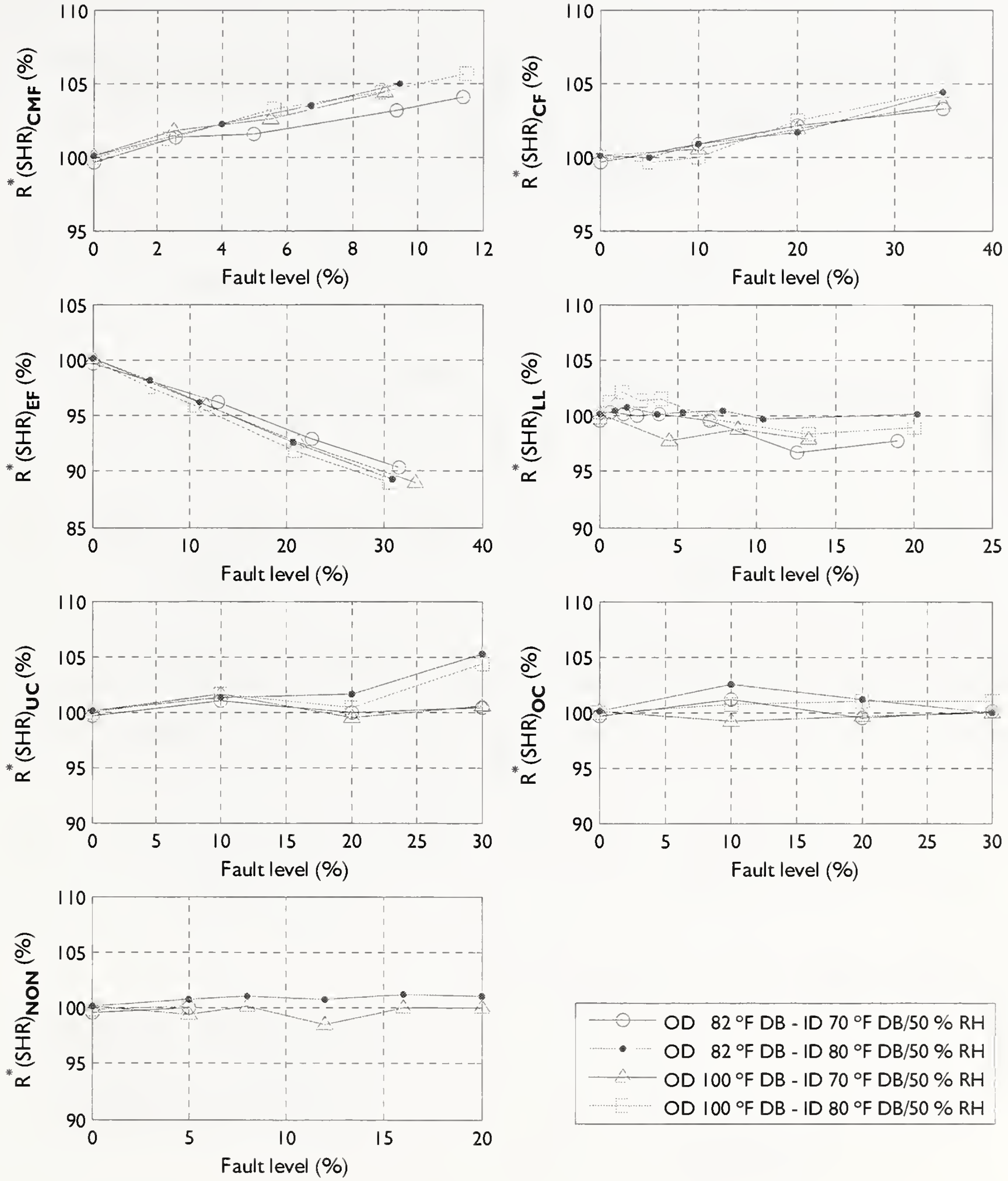


Figure 5.20. Variation of indoor air sensible heat ratio (SHR) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

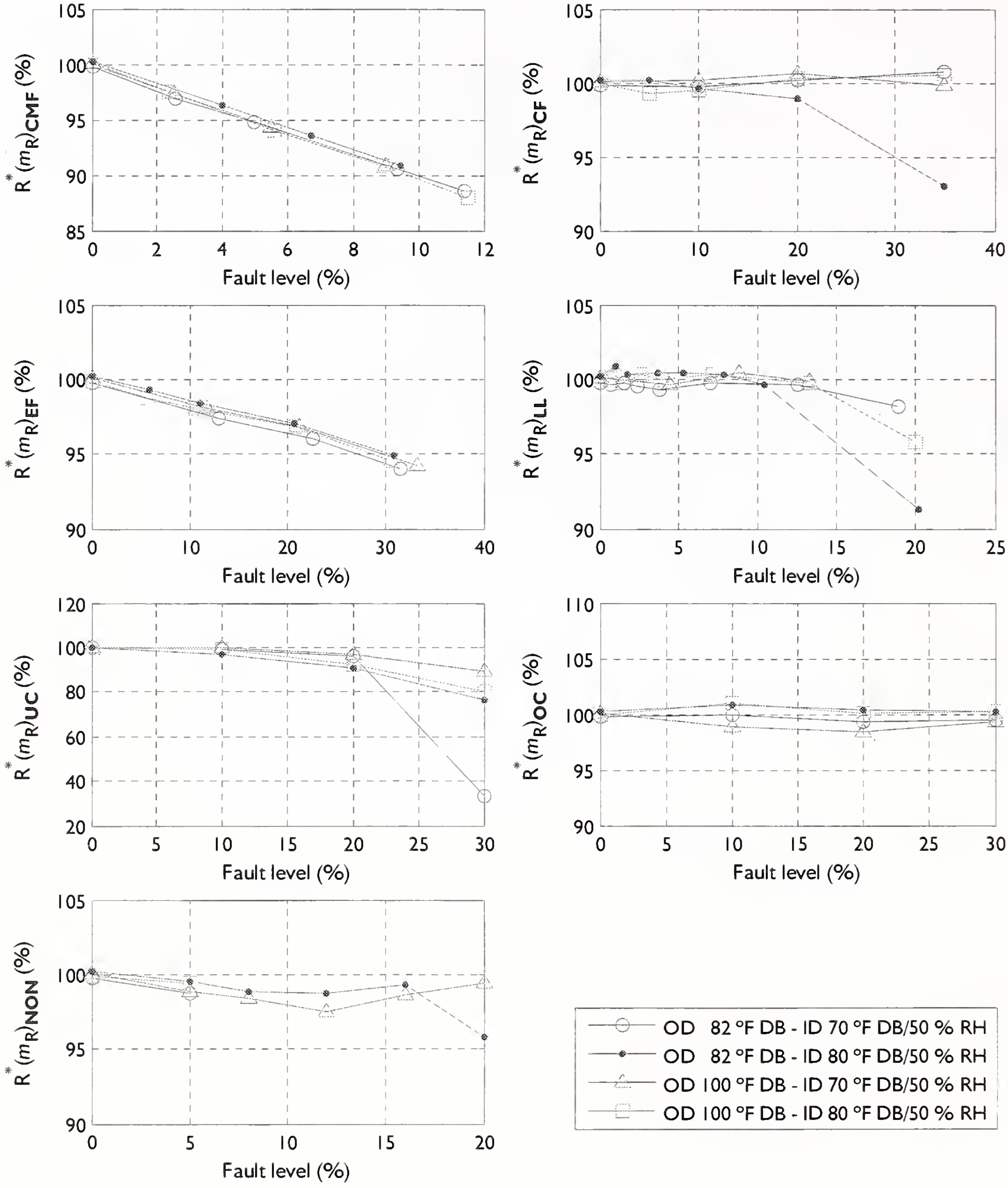


Figure 5.21. Variation of refrigerant mass flow rate (m_R) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

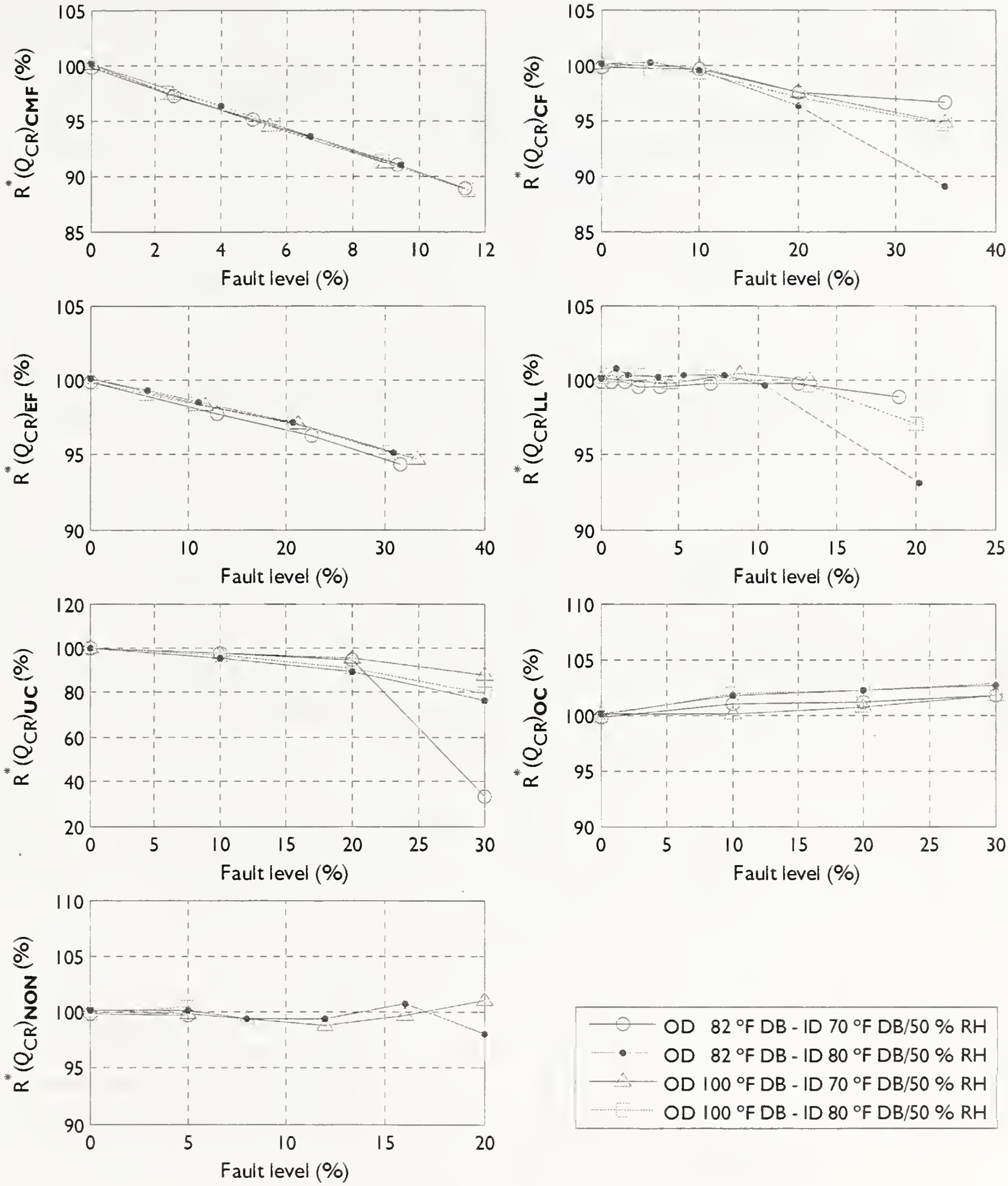


Figure 5.22. Variation of condenser refrigerant-side capacity (Q_{CR}) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

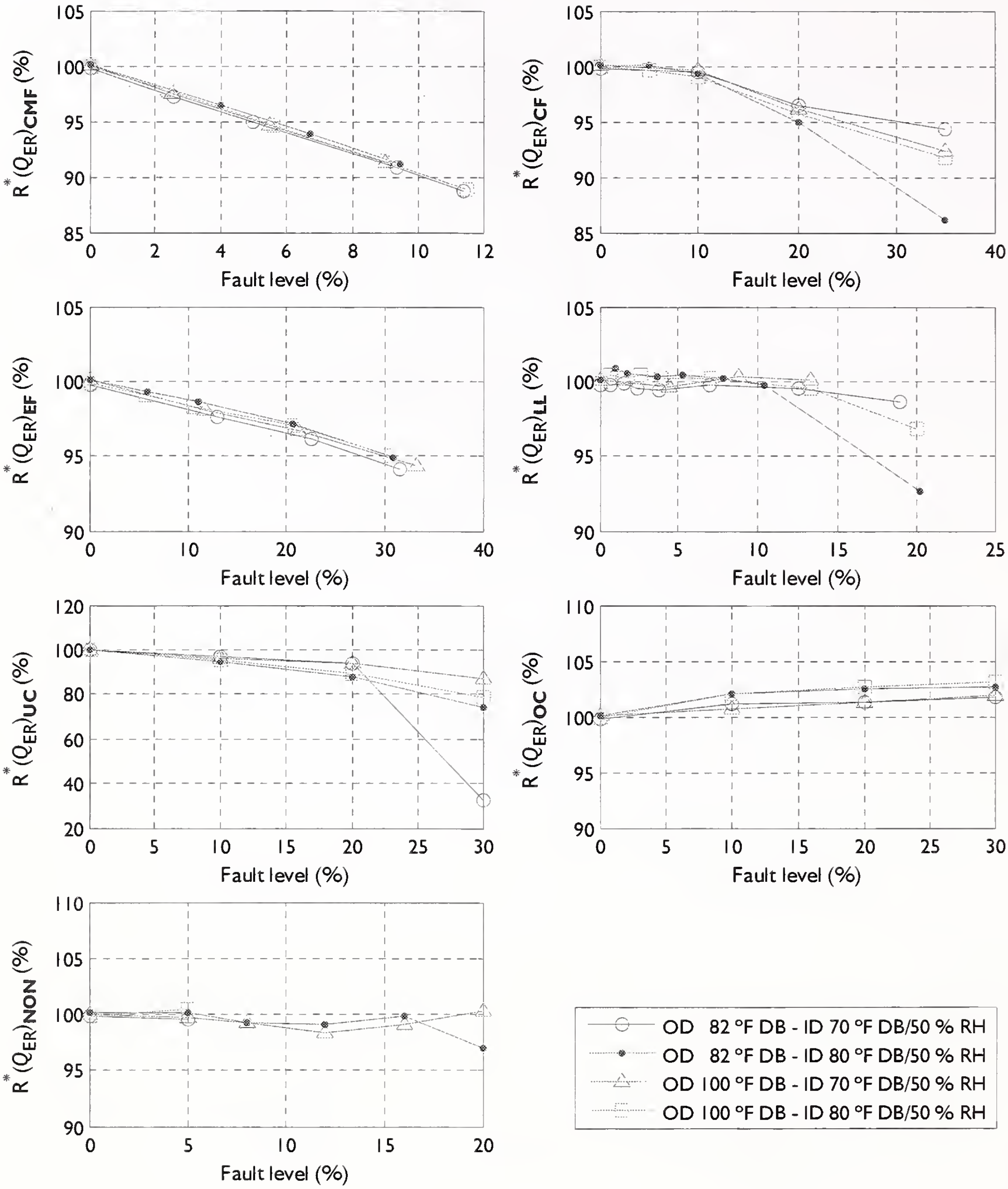


Figure 5.23. Variation of evaporator refrigerant-side capacity (Q_{ER}) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

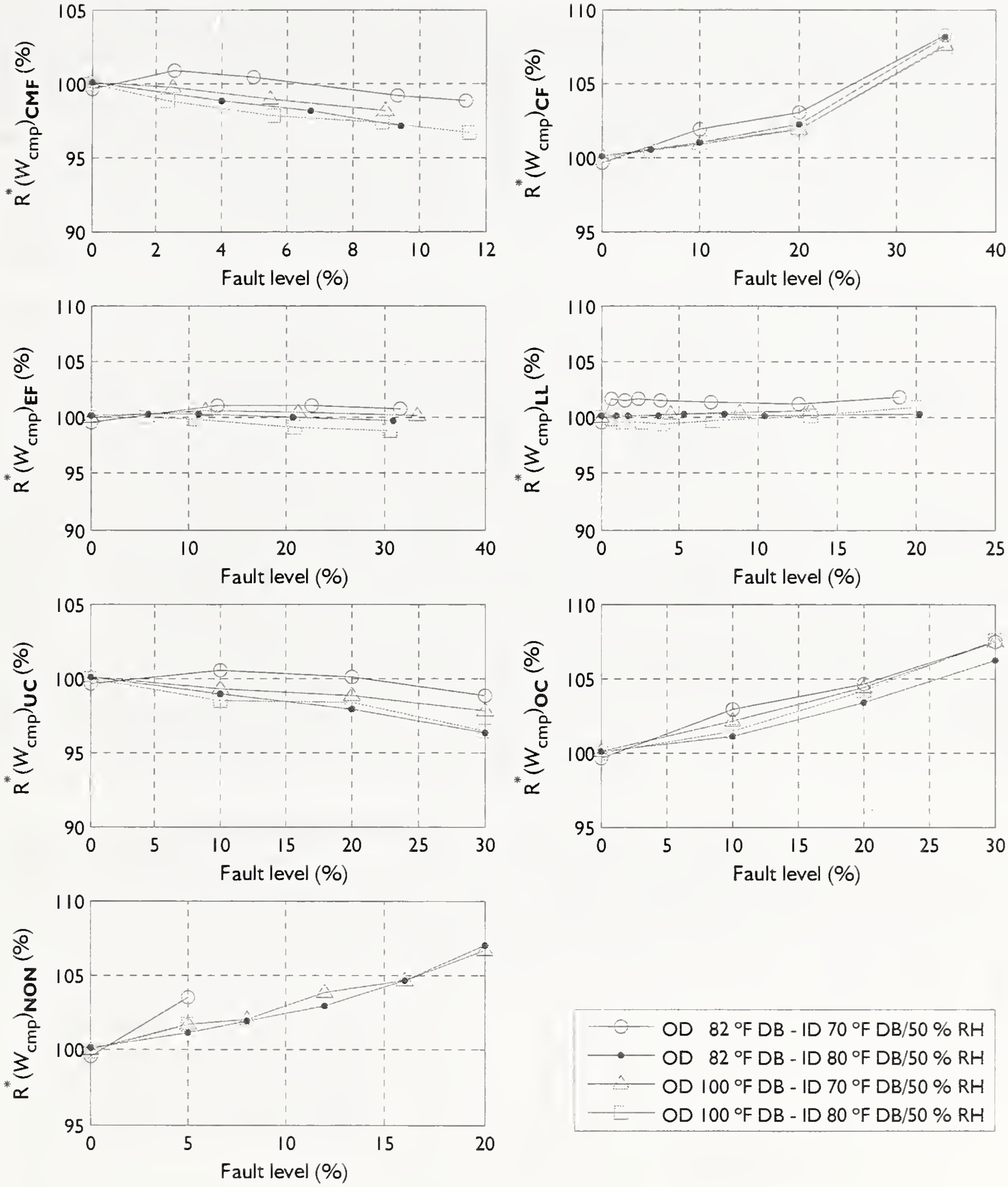


Figure 5.24. Variation of compressor work (W_{cmp}) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

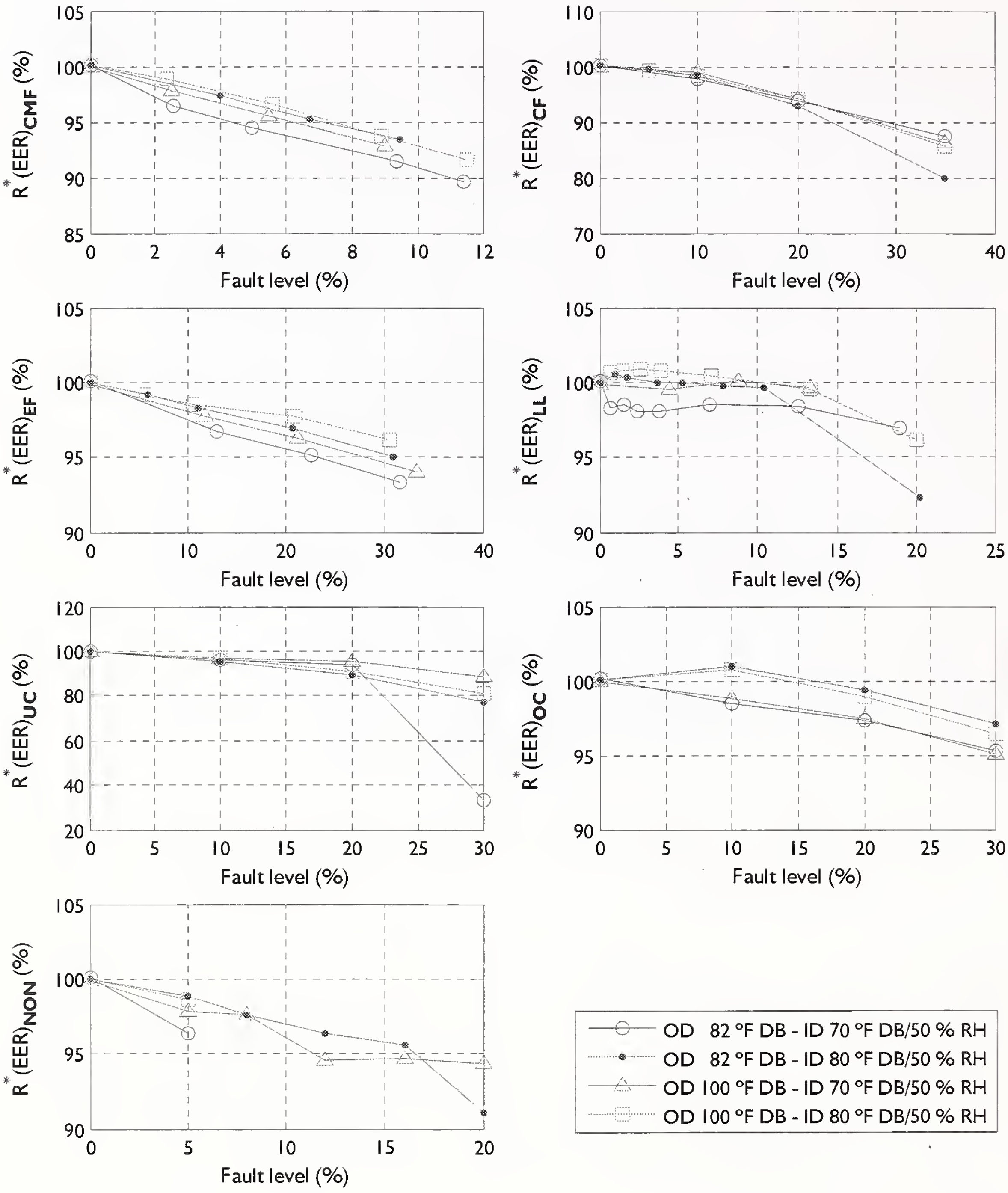


Figure 5.25. Variation of energy efficiency ratio (EER) at different faults. From the top left to right: compressor fault (CMF), improper outdoor air flow rate (CF), improper indoor air flow rate (EF), liquid line restriction (LL), refrigerant overcharge (OC), refrigerant undercharge (UC), and presence of non-condensable gases (NON)

5.3 Transient Behavior at Different Refrigerant Charge Levels

Figure 5.26 represents a sample of a transient test at the condition of 37.8 °C (100.0 °F) outdoor dry bulb temperature, 21.1 °C (70.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity (Test #8). The refrigerant charge level was 20 % undercharged. The test was done with on-off cyclic operation with different turn-off intervals. Five temperature measurements, condenser saturation temperature (T_{CR}), evaporator saturation temperature (T_{ER}), compressor discharge wall temperature (T_{DW}), evaporator exit superheat (ΔT_{sh}), and liquid line subcooling (ΔT_{sc}) were recorded every 5 s. As shown at the top of Figure 5.26, the turn-off period varied with (24, 24, 6, and 12) min off with a 6 min on-period in between each off period. The first two 24 minute off-periods were intended to verify the repeatability of any startup transients.

Figure 5.27 shows the time variation of measurements during on-off cyclic operation with different turn-off intervals at the normal refrigerant charge. Without regard to the turn-off period, all the measurements show similar transient behavior. Less variation during the turn-on transients is observed when the system is turned off for a shorter period. Based on the superheat change in Figure 5.27(d), the TXV behavior can be indirectly estimated. The TXV is mostly closed during the off period since superheat is less than the normal level which is approximately 8.3 °C (15.0 °F). Right after the system is turned on, the TXV is still closed and superheat decreases. Shortly thereafter, the TXV is opened due to increased superheat since there is no refrigerant supply through the TXV. After the TXV opens, liquid refrigerant flows out of the evaporator. This drops superheat to nothing, meaning two-phase flow, and the TXV shuts again. After the liquid refrigerant evaporates, the TXV reopens and then starts to control superheat. This trend is also shown in the evaporator saturation temperature in Figure 5.27(b) and refrigerant mass flow rate in Figure 5.27(f). Figure 5.27(e) shows the variation of liquid line subcooling. A little while after startup, subcooling is slowly increased to a desired value as expected. In the current system, the subcooling thermocouple was attached right before the TXV. After the system was turned off, the temperature at the TXV upstream gradually approaches the indoor temperature of 21.1 °C (70.0 °F). Since the condenser and liquid line pressure stayed at about the same level, corresponding to the saturation temperature of 37.8 °C (100.0 °F), subcooling increases after the system shutdown.

Figure 5.28 shows time variation of measurements with different refrigerant charge levels. Normal refrigerant charge, 20 % undercharge, and 30 % undercharge were selected. The system was cyclically operated for 24 min off, 6 min on, and 24 min off. Distinct differences during the off period are not observed. During the on period, superheat variation in Figure 5.28(d) shows that transient behaviors vary with charge levels; however, the observed differences are not large enough for use by a FDD scheme for detecting improper refrigerant charge in the system.

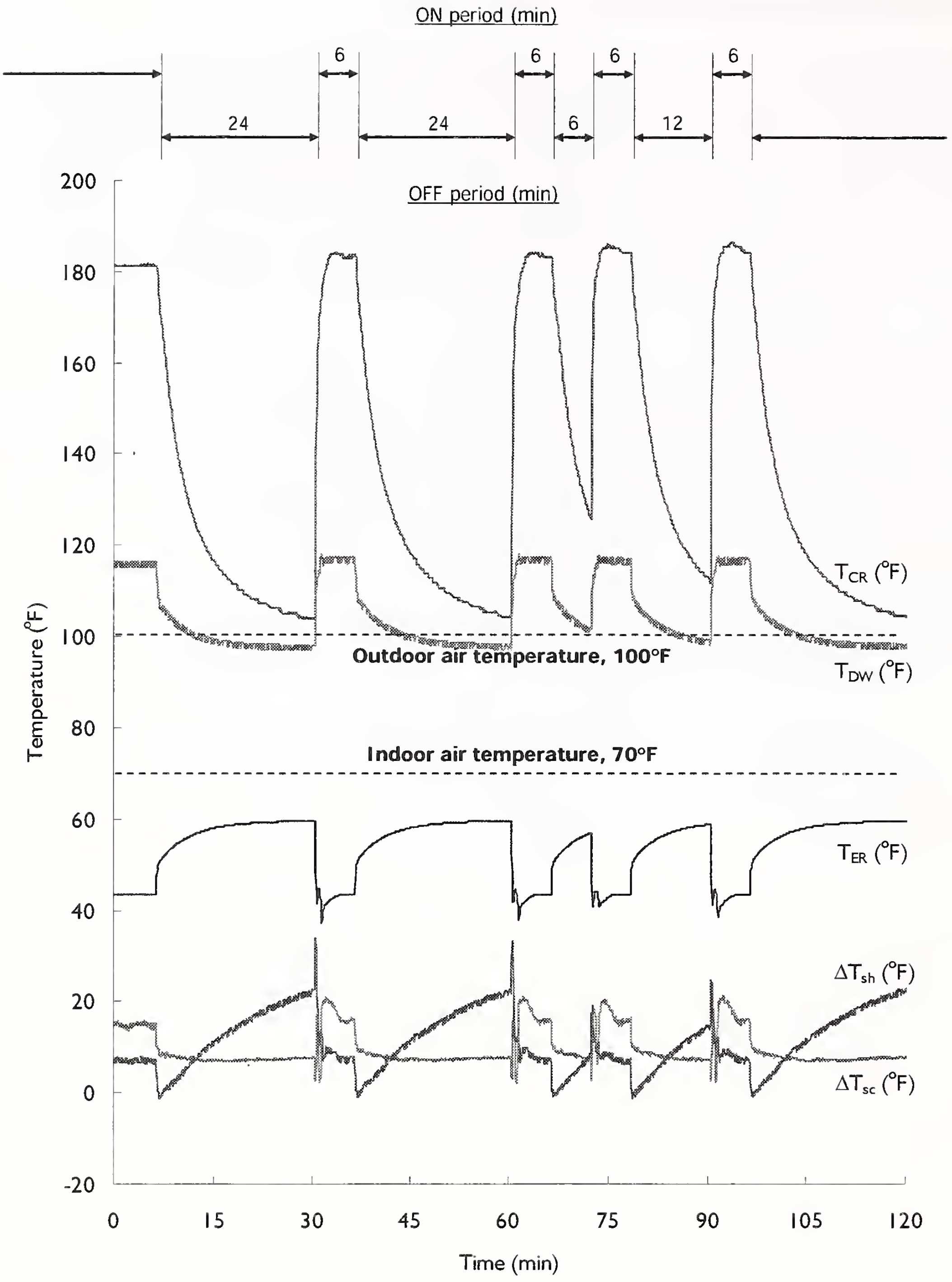
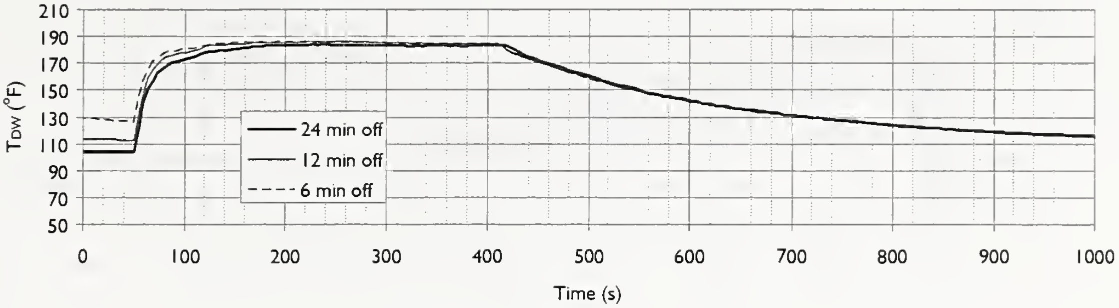
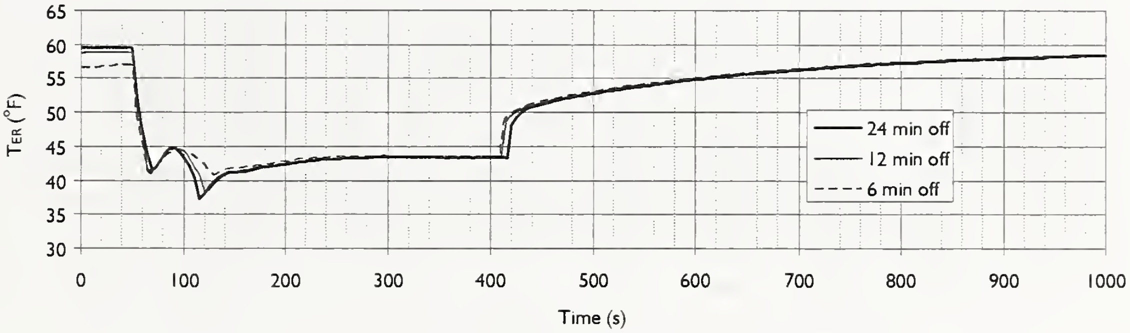


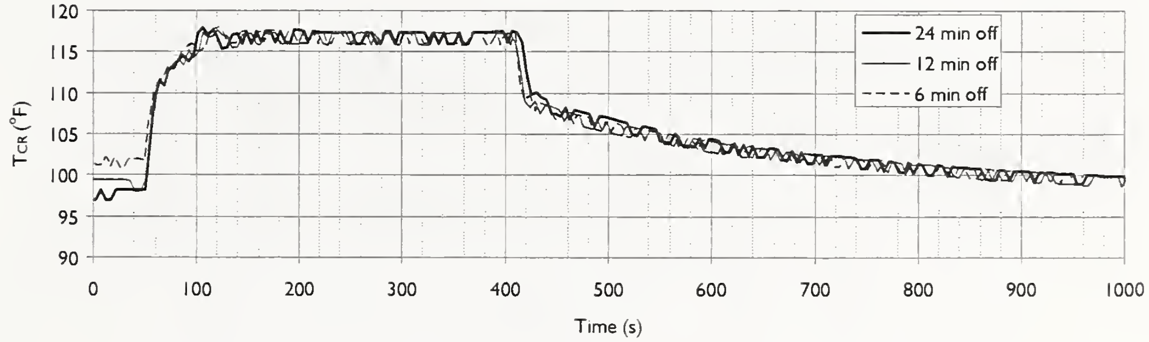
Figure 5.26. Real-time transient test of on-off cyclic operation with different turn-off intervals at the 20 % fault of refrigerant undercharge fault (Test #8: 37.8 °C (100.0 °F) outdoor dry bulb temperature, 21.1 °C (70.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)



(a) Compressor discharge wall temperature

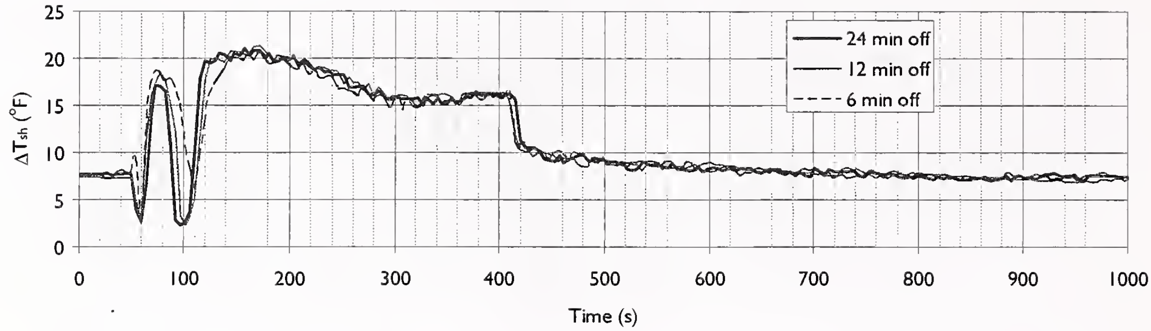


(b) Evaporator exit saturation temperature

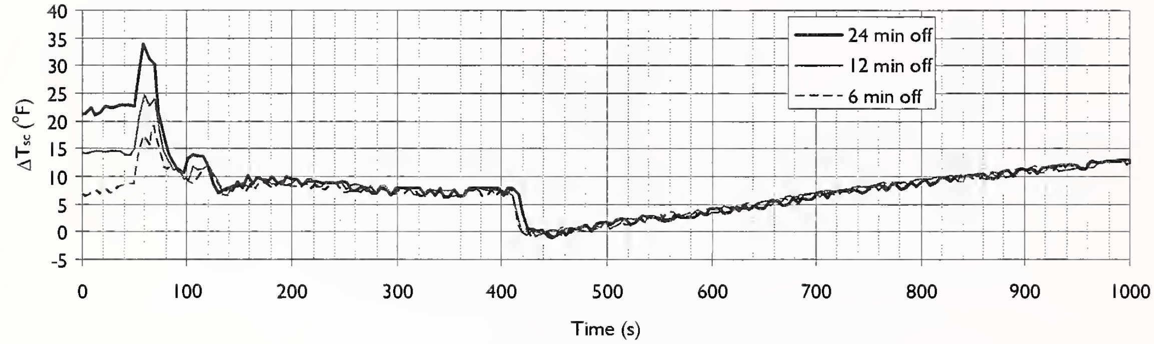


(c) Condenser inlet saturation temperature

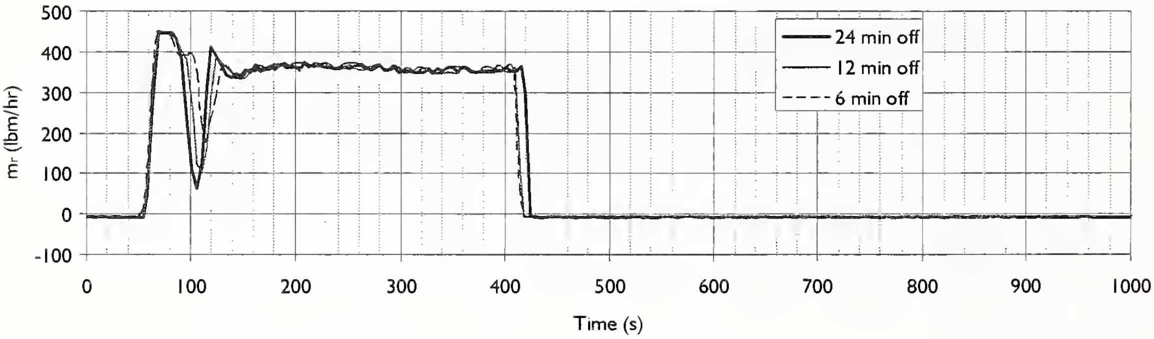
Figure 5.27. Time variation of measurements during on-off cyclic operation with different turn-off intervals at the normal refrigerant charge (Test #8: 37.8 °C (100.0 °F) outdoor dry bulb temperature, 21.1 °C (70.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)



(d) Evaporator exit superheat

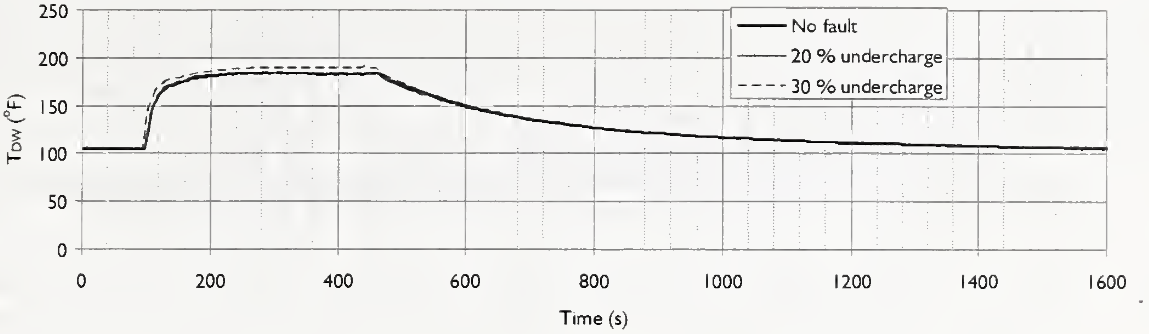


(e) Condenser exit liquid line subcooling

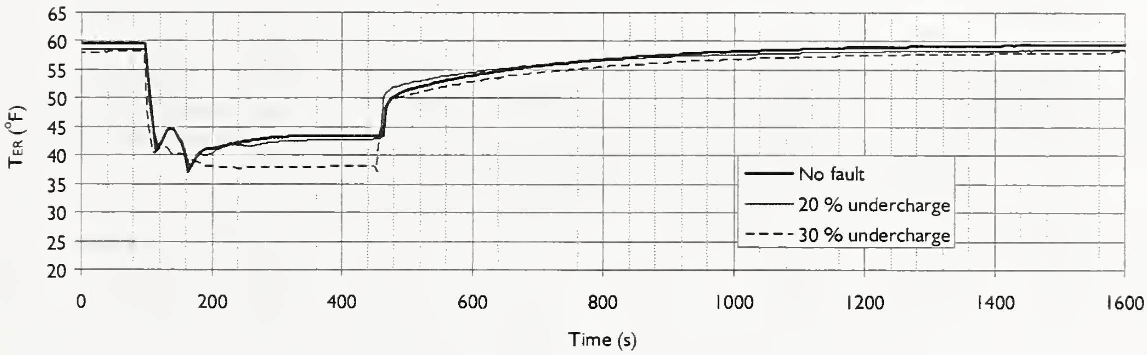


(f) Refrigerant mass flow rate

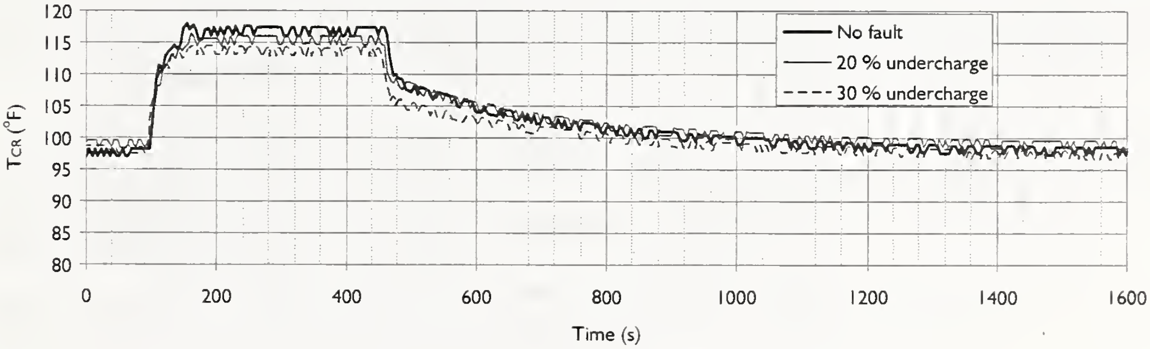
Figure 5.27. Time variation of measurements during on-off cyclic operation with different turn-off intervals at the normal refrigerant charge (Test #8: 37.8 °C (100.0 °F) outdoor dry bulb temperature, 21.1 °C (70.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity) (continued)



(a) Compressor discharge wall temperature

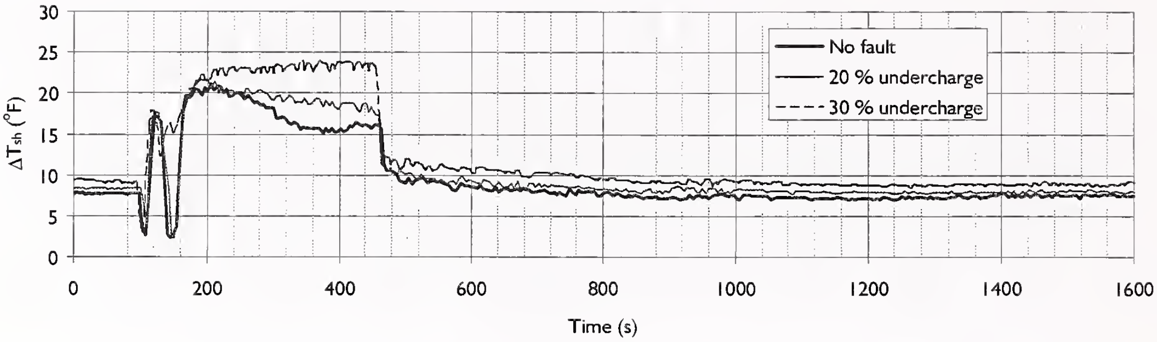


(b) Evaporator exit saturation temperature

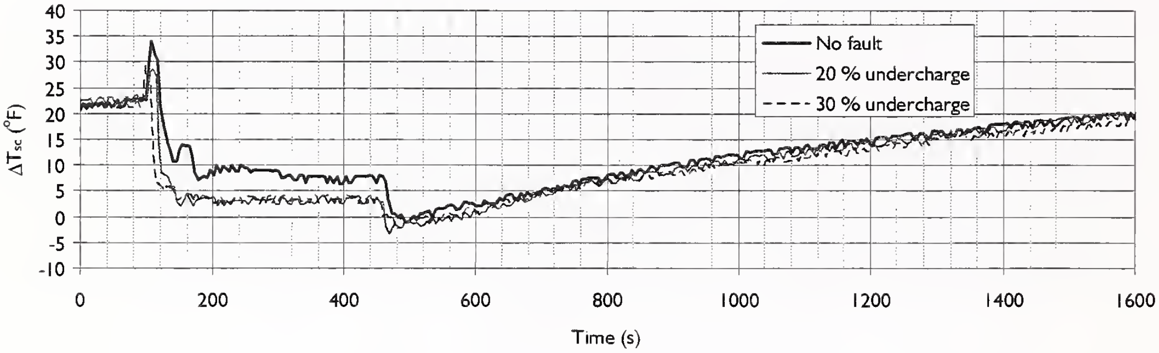


(c) Condenser inlet saturation temperature

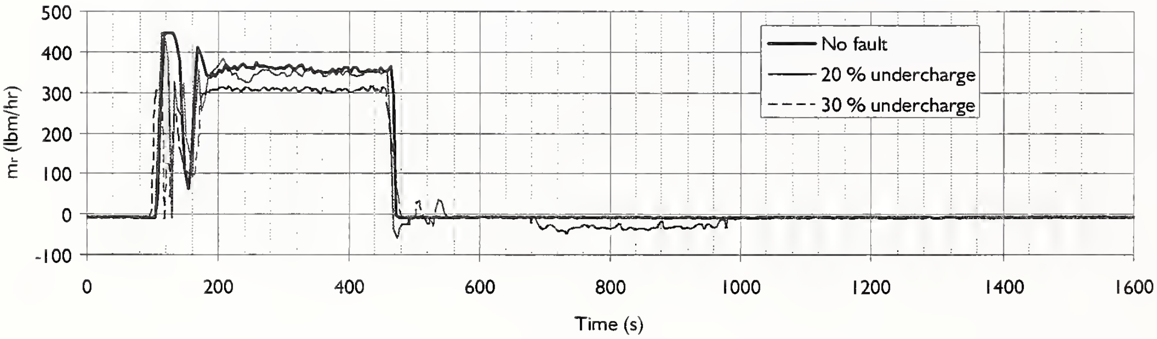
Figure 5.28. Time variation of measurements during on-off cyclic operation with different refrigerant charge levels (Turn-off period: 24 min, Test #8: 37.8 °C (100.0 °F) outdoor dry bulb temperature, 21.1 °C (70.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity)



(d) Evaporator exit superheat



(e) Condenser exit liquid line subcooling



(f) Refrigerant mass flow rate

Figure 5.28. Time variation of measurements during on-off cyclic operation with different refrigerant charge levels (Turn-off period: 24 min, Test #8: 37.8 °C (100.0 °F) outdoor dry bulb temperature, 21.1 °C (70.0 °F) indoor dry bulb temperature and 50 % indoor relative humidity) (continued)

CHAPTER 6. CONCLUDING REMARKS

This report provides basic information on the behavior of a R410A residential unitary split heat pump during no-fault and fault operation. The system was installed in two separate environmental chambers and was operated in the cooling mode. Superheat at the evaporator exit was controlled by a TXV. The system was modified to implement seven artificial faults: compressor/reversing valve leakage, improper outdoor air flow, improper indoor air flow, liquid line restriction, refrigerant undercharge, refrigerant overcharge, and presence of non-condensable gas. These faults were imposed at two or more levels.

To estimate the reference values of the system behavior, no-fault tests were performed. The no-fault test results were used in the formulation of the reference model, which consisted of 2nd order multivariate regressive polynomials calculated as a function of three input parameters: outdoor air temperature, indoor air temperature, and indoor dew point temperature. The developed steady-state detector calculated standard deviations of liquid line subcooling and evaporator exit superheat measurements for determining whether the system reached steady state. The steady-state detector filtered measured data based on a moving window and thresholds. In this study, at least 12 min were monitored to minimize false steady-state indications.

Using the no-fault model as a reference, feature residuals were observed for single faults. Since the system was controlled by a TXV, the system could adapt itself to external variation very well. Thus faulty behavior was not as clear as would be the case for a system equipped with an orifice expansion device; however, some measurements showed enough large variations to detect faults.

The distinctiveness of a fault depended on the TXV status. For the tests with liquid line restriction, little variation was observed due to the TXV's control of superheat. But once the liquid line was restricted until the subcooled refrigerant started to flash, even the maximum opening of the TXV could not control the superheat, and the system responded like a fixed orifice system. In this case, a TXV with a larger orifice size would be required, which implies that the fault effect is also influenced by the effective orifice size of the TXV.

For the heat exchanger fault caused by improper air flow, the fault behavior depends on the sizing of the heat exchanger. Oversizing the heat exchanger or fan capacity makes the system more robust in the presence of an improper air flow fault. Installing a liquid line receiver could also mollify the refrigerant undercharge/overcharge fault and non-condensable gas fault.

The dynamic tests at different refrigerant charges showed minor effects on the system behavior for various off-periods between shutoff and startup of the system. The most influenced parameter was the evaporator exit temperature; however, none of the monitored features varied sufficiently to diagnose improper refrigerant charge.

The results reported here will be used in a follow-up study for the development of FDD methods for air-conditioners and heat pumps operating in the cooling mode.

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APPENDIX A. LIST OF LABORATORY INSTRUMENTATION

Table A.1. Data acquisition channel assignment for FDD split-system testing[1]

Channel	Sensor type	Description
0	T-type thermocouple	(Indoor) Nozzle Temp on pitot probe
1	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 1
2	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 2
3	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 3
4	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 4
5	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 5
6	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 6
7	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 7
8	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 8
9	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 9
10	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 10
11	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 11
12	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 12
13	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 13
14	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 14
15	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 15
16	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 16
17	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 17
18	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 18
19	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 19
20	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 20
21	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 21
22	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 22
23	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 23
24	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 24
25	T-type thermocouple	(Indoor) Exit Air Grid, T-couple 25
26	T-type thermocouple	(Outdoor) Cond Inlet Air flow #2
27	T-type thermocouple	(Outdoor) Cond Inlet Air flow #5
28		N/A
29	T-type thermocouple	(Outdoor) Cond Inlet Air flow #4
30		N/A
31	T-type thermocouple	(Outdoor) Comp Suction - Well Temp
32	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 1
33	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 2
34	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 3
35	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 4
36	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 5
37	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 6
38	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 7
39	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 8
40	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 9
41	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 10
42	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 11

Channel	Sensor type	Description
43	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 12
44	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 13
45	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 14
46	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 15
47	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 16
48	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 17
49	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 18
50	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 19
51	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 20
52	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 21
53	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 22
54	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 23
55	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 24
56	T-type thermocouple	(Indoor) Inlet Air Grid, T-couple 25
57	T-type thermocouple	(Indoor) Evap Bend 23 - 24 R
58	T-type thermocouple	(Indoor) Evap Outlet (11) R
59	T-type thermocouple	(Indoor) Evap Bend 27 - 28 R
60		N/A
61	T-type thermocouple	(Indoor) Cond Inlet 2nd bunch (Large diameter tubing)
62	T-type thermocouple	(Outdoor) Comp Discharge Line Wall
63	T-type thermocouple	(Outdoor) Cond Inlet Air flow #3
64		N/A
65		N/A
66		N/A
67	T-type thermocouple	(Indoor) Evap Bend 12 - 13 R
68	T-type thermocouple	(Indoor) Vapor Ref Evap exit #2 Well
69	T-type thermocouple	(Indoor) Vapor Ref Evap Exit #1 Well
70		N/A
71	T-type thermocouple	(Indoor) Liq Ref Evap Inlet #2
72		N/A
73	T-type thermocouple	(Indoor) Liq Ref Evap Inlet #1
74	T-type thermocouple	(Indoor) Evap Bend 53 - 54 L
75	T-type thermocouple	(Indoor) Evap Bend 16 - 17 R
76	T-type thermocouple	(Indoor) Evap Bend 20 - 40 R
77	T-type thermocouple	(Indoor) Evap Outlet, L exit 11
78	T-type thermocouple	(Indoor) Evap Bend 53 - 54 R
79	T-type thermocouple	(Indoor) Evap Bend 27 - 28 L
80	T-type thermocouple	(Indoor) Evap Bend 13 - 12 L
81	T-type thermocouple	(Indoor) Evap Bend 17 - 16 L
82	T-type thermocouple	(Indoor) Evap Bend 57 - 58 R
83	T-type thermocouple	(Indoor) Evap Bend 40 - 20 L
84	T-type thermocouple	(Indoor) Evap Bend 57 - 58 L
85	T-type thermocouple	(Indoor) Outlet Air Temp#1 @ MEMS RH Sensor
86	T-type thermocouple	(Indoor) Evap Bend 23 - 24 L
87	T-type thermocouple	(Outdoor) Comp Shell - TOP
88	T-type thermocouple	(Outdoor) Comp Suction Line - Wall
89	T-type thermocouple	(Indoor) Outlet Air Temp#2 @ MEMS RH Sensor
90	T-type thermocouple	(Outdoor) Cond Exit Air flow Temp #1 ON TOP OF FAN

Channel	Sensor type	Description
91	T-type thermocouple	(Outdoor) Fan Motor Case Temp (F)
92	T-type thermocouple	(Outdoor) Cond Exit Air flow Temp #2 ON TOP OF FAN
93	T-type thermocouple	(Indoor) Coriollis Flow Meter Inlet Temp - Wall
94	T-type thermocouple	(Outdoor) Cond Internal Air Right side wrt Comp
95	T-type thermocouple	(Outdoor) Cond Internal Air Left side wrt Comp
96	T-type thermocouple	(Outdoor) Cond Inlet Air flow Temp #1
97	T-type thermocouple	(Outdoor) Cond Air flow Inlet Temp #6
98	T-type thermocouple	(Outdoor) Cond Outlet - 2nd Bunch (on small feeder tube)
99	T-type thermocouple	(Outdoor) Liq Line Temp @ Service Valve
100	T-type thermocouple	(Outdoor) Comp Shell at Bottom - Oil Level
101	T-type thermocouple	(Outdoor) Vapor Temp @ Service Valve
102	AP transducer	(Outdoor) P1, Comp Discharge Pressure, VDC
103	AP transducer	(Outdoor) P2, Vapor Coil Inlet, VDC
104	AP transducer	(Outdoor) P6, Vapor Service Valve, VDC
105	AP transducer (0-500 psia)	(Outdoor) P5, Comp Suction, VDC
106		N/A
107	DP transducer (0-1" H_2O)	(Outdoor) Coil Air DP, 0-5 VDC
108	DP transducer (0-1" H_2O)	(Indoor) Nozzle AIR DP #2, 0-5 VDC
109	DP transducer (0-10 psid)	(Indoor) Coil Refrig DP, 0.05-5.05VDC
110	DP transducer (0-25 psid)	(Outdoor) Coil Refrig DP, 0-5 VDC
111	DP transducer (0-25 psid)	(Outdoor) Liquid line Refrig DP, 0.05-5.05 VDC
112	Coriolis mass flow meter	(Indoor) Refrigerant mass flow meter @ Evap Inlet, lbm/h
113	Coriolis mass flow meter (30-120 lbm/ft3)	(Indoor) Refrigerant density @ Evap Inlet
114	DP transducer	(Indoor) Evap Coil Airside DP (in H2O)
115	DP transducer	(Indoor) Nozzle DP in Airchamber (in H2O)
116	Dewpoint sensor	(Indoor) Evap Inlet Dewpoint (F)
117	Dewpoint sensor	(Indoor) Evap Exit Dewpoint (F)
118		N/A
119	RH sensor	(Indoor) MEMS Sensor, Inlet RH%
120	T-type thermocouple	(Indoor) Airside Evap Tpile voltage, VDC
121	Barometric pressure transducer	Barometric Pressure, 0-10 VDC
122	RH sensor	(Indoor) MEMS Sensor, Exit RH%
123	DC Power meter	(Indoor) MEMS Sensor Power Supply Voltage (VDC)
124		N/A
125	AP transducer (0-500 psia)	(Indoor) Overall evap exit pres
126	AP transducer (0-500 psia)	(Outdoor) Liquid Line Pres @ Service Valve
127	AP transducer (0-500 psia)	(Indoor) Evap Inlet Liquid Pres, VDC

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[1] In Figure 3.8, numbers less than 128 are identical with channel number in Table A.1. Numbers over 127 can be calculated by the listed measurements in Table A.1.

Table A.2. Post-processed data list for FDD analysis

List #	**Abbreviation**	**BG unit**	**SI unit**
0	Barometric Pressure	inHg	kPa
1	OD Air Inlet Temp	°F	°C
2	OD Air Inlet DewPoint Temp	°F	°C
3	OD Air Inlet Relative Humidity	-	-
4	OD Air Inlet Density	lbm/ft^3	kg/m^3
5	OD Air Temp Increase	°F	°C
6	OD Air Exit Temp	°F	°C
7	OD Air Flow Rate	SCFM	m^3/s
8	ID Air Inlet Temp	°F	°C
9	ID Air Inlet DewPoint Temp	°F	°C
10	ID Air Inlet Rel Humidity	-	-
11	ID Air Inlet Density	lbm/ft^3	kg/m^3
12	ID Air Temp Drop	°F	°C
13	ID Air Exit Temp	°F	°C
14	ID Air Exit DewPoint Temp	°F	°C
15	ID Air Exit Rel Humidity	-	-
16	ID Air Flow Rate	SCFM	m^3/s
17	ID Sensible Capacity	Btu/h	W
18	ID Latent Capacity	Btu/h	W
19	ID Air Total Capacity	Btu/h	W
20	ID Air Sensible Heat Ratio	-	-
21	COMP Suction Temp	°F	°C
22	COMP Discharge Temp	°F	°C
23	COND Inlet Temp	°F	°C
24	COND Inlet Pressure	psia	kPa
25	COND Inlet Tsat	°F	°C
26	COND Exit Temp	°F	°C
27	COND Exit Pressure	psia	kPa
28	COND Exit Tsat	°F	°C
29	COND Exit Subcooling	°F	°C
30	COND DP	psid	kPa
31	TXV Upstream P	psia	kPa
32	Liquid Line DP	psia	kPa
33	Liquid Line DT	°F	°C
34	Refrigerant Flow Rate	lbm/h	kg/s
35	TXV DP	psia	kPa
36	EVAP Inlet Temp	°F	°C
37	EVAP Exit Temp	°F	°C
38	EVAP Exit Pressure	psia	kPa
39	EVAP Exit Tsat	°F	°C
40	EVAP Exit Superheat	°F	°C
41	EVAP DP	psid	kPa
42	COND Capacity	Btu/h	W
43	EVAP Capacity	Btu/h	W
44	COMP Power	W	W
45	EER(BG)/COP(SI)	Btu/h.W	-

APPENDIX B. COEFFICIENTS OF MULTIVARIATE REFERENCE MODEL

Table B.1. Coefficients of second order multivariate polynomial reference model in Equation (4.7b) for selected features and parameters for no-fault estimation

$$\phi_i = a_0 + a_1 T_{OD} + a_2 T_{ID} + a_3 T_{IDP} + a_4 T_{OD} T_{ID} + a_5 T_{ID} T_{IDP} + a_6 T_{IDP} T_{OD} + a_7 T_{OD}^2 + a_8 T_{ID}^2 + a_9 T_{IDP}^2 \quad ^1$$

Feature/ parameters	unit	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9
T_{ER}	°F	4.37E+05	-1.57E+02	-1.08E+04	-3.69E+02	-6.76E-01	1.04E+01	1.87E+00	1.25E-01	7.20E+01	-8.90E+00
ΔT_{sh}	°F	-1.16E+05	1.23E+02	2.93E+03	1.51E+02	1.35E+00	-1.44E+01	-3.32E+00	-7.18E-01	-1.71E+01	1.66E+01
T_{DW}	°F	6.78E+00	-1.52E-03	-1.49E-01	-1.16E-02	-7.82E-05	6.46E-04	6.69E-05	3.22E-05	8.94E-04	-5.86E-04
T_{CR}	°F	-1.15E+03	1.83E+00	3.48E+01	5.69E-02	1.61E-02	-1.22E-01	-7.23E-03	-1.54E-02	-1.85E-01	1.24E-01
ΔT_{sc}	°F	1.20E+03	7.21E+01	5.56E+02	3.34E+01	-4.84E-01	-7.60E+00	-1.17E+00	-3.46E-01	5.10E-01	8.32E+00
ΔT_{CA}	°F	-1.19E+04	1.11E+02	7.71E+02	4.14E+01	-9.11E-01	-7.38E+00	-1.28E+00	-9.15E-01	-7.42E-01	8.14E+00
ΔT_{EA}	°F	-1.93E+03	-1.08E+01	8.47E+01	-9.05E+00	-3.15E-02	3.01E-01	5.06E-03	2.22E-01	-6.01E-01	-1.54E-01
ΔT_{LL}	°F	8.24E+01	-3.05E-01	-1.36E+00	1.35E-01	-1.46E-03	-6.21E-03	-1.10E-03	1.12E-03	1.23E-02	5.35E-03
$Q_{EA,sens}$	Btu/h	4.26E+01	1.36E-01	-9.02E-01	6.75E-02	1.66E-03	-1.13E-02	-1.88E-03	-3.81E-04	1.17E-02	1.25E-02
$Q_{EA,lat}$	Btu/h	-1.89E+00	-3.68E-01	6.74E-01	5.77E-02	-3.05E-03	4.74E-03	-1.41E-03	3.46E-03	-2.84E-03	-3.03E-03
SHR	-	2.72E+02	1.02E+00	-6.01E+00	-2.25E-02	-1.11E-02	2.08E-02	-2.84E-03	8.73E-03	4.08E-02	-1.51E-02
m_R	lbm/h	1.08E+02	1.19E+00	-2.80E+00	3.52E-02	-4.19E-04	9.65E-04	-9.30E-04	-8.23E-04	1.99E-02	2.86E-04
Q_{CR}	Btu/h	5.48E+02	-2.31E-01	-1.42E+01	-3.71E-02	1.34E-03	7.83E-03	-8.02E-04	6.98E-04	9.25E-02	-5.18E-03
Q_{ER}	Btu/h	-1.96E+01	1.47E-01	5.62E-01	2.96E-02	-5.75E-04	5.51E-04	-7.00E-04	-4.11E-04	-2.53E-03	4.27E-04
W_{cmp}	W	2.10E+02	1.96E-02	-5.16E+00	-1.64E-01	-1.53E-03	1.23E-02	1.69E-03	-3.68E-04	3.46E-02	-1.23E-02
EER	Btu/h.W	8.69E+00	1.04E-01	-3.14E-01	-1.36E-02	-2.19E-04	4.29E-04	-6.21E-05	-3.38E-04	1.86E-03	-1.72E-04

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[1] Input temperature parameters of T_{ID}, T_{OD}, and T_{IDP} have the unit of °F. The features and parameters ϕ_i are interpolated within the range of 21.1 °C (70.0 °F) $\leq T_{ID} \leq$ 26.7 °C (80.0 °F) and 21.1 °C (70.0 °F) $\leq T_{OD} \leq$ 37.8 °C (100.0 °F). The interpolation range for T_{IDP} is associated with the test condition from dry coil evaporator condition to relative humidity of 50 %. For example, -1.1 °C (30.0 °F) $\leq T_{IDP} \leq$ 10.3 °C (50.5 °F) for T_{ID} = 21.1 °C (70.0 °F) and -1.1 °C (30.0 °F) $\leq T_{IDP} \leq$ 15.8 °C (60.4 °F) for T_{ID} = 26.7 °C (80.0 °F).

APPENDIX C. EXTENDED PERFORMANCE CHARTS

Charts of an additional 16 parameters are plotted for no-fault and single-fault tests. These charts are extended plots of single-fault plots in section 5.1. Below is the list of 16 parameters.

SCFM_{CA}	outdoor air flow rate (ft^3/min)
ϕ_{EAI}	indoor air inlet relative humidity
T_{EAOD}	indoor air exit dew point temperature (°F)
ϕ_{EAO}	indoor air exit relative humidity
SCFM_{EA}	indoor air flow rate (ft^3/min)
T_{SW}	compressor suction wall temperature (°F)
T_{CRI}	condenser refrigerant inlet temperature (°F)
P_{CRI}	condenser refrigerant inlet pressure (psia)
$T_{\text{CRO,sat}}$	condenser refrigerant exit saturation temperature (°F)
ΔP_{CR}	condenser refrigerant pressure drop (psid)
$P_{\text{TXV,up}}$	TXV upstream pressure (psia)
ΔP_{LL}	liquid line pressure drop (psid)
T_{ERI}	evaporator refrigerant inlet temperature (°F)
P_{ERO}	evaporator refrigerant exit pressure (psia)
ΔP_{ER}	evaporator refrigerant pressure drop (psid)
$\Delta T_{\text{sh}} - \Delta T_{\text{sc}}$	difference between superheat and subcooling (°F)

C.1 No-Fault Tests

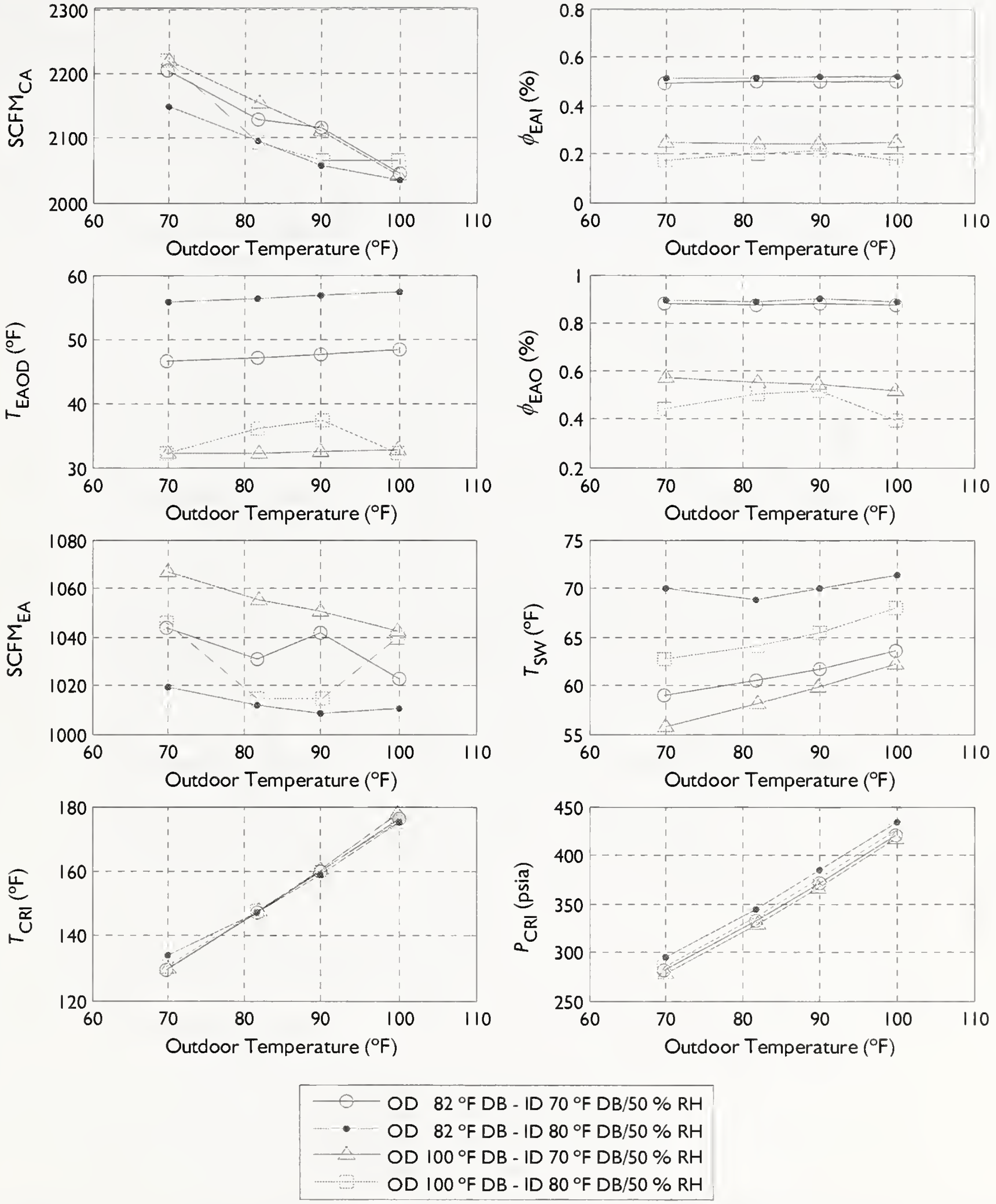

Figure C.1. Selected parameters from the no-fault tests. From the top left to right: SCFM$_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, SCFM$_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

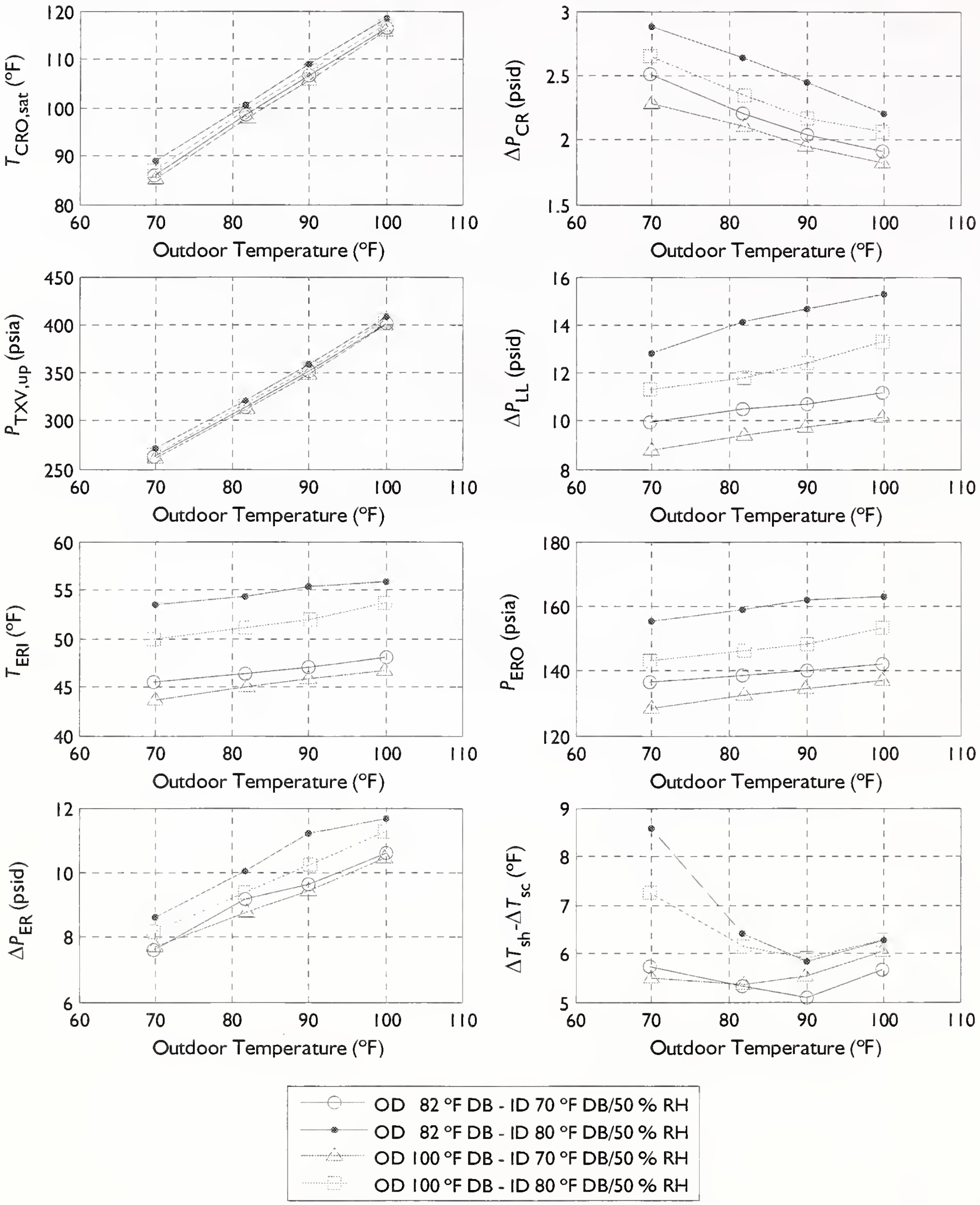

Figure C.2. Selected parameters from the no-fault tests. From the top left to right: $T_{CRO,sat}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{TXV,up}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{sh} - \Delta T_{sc}$

C.2 Single-Fault Tests

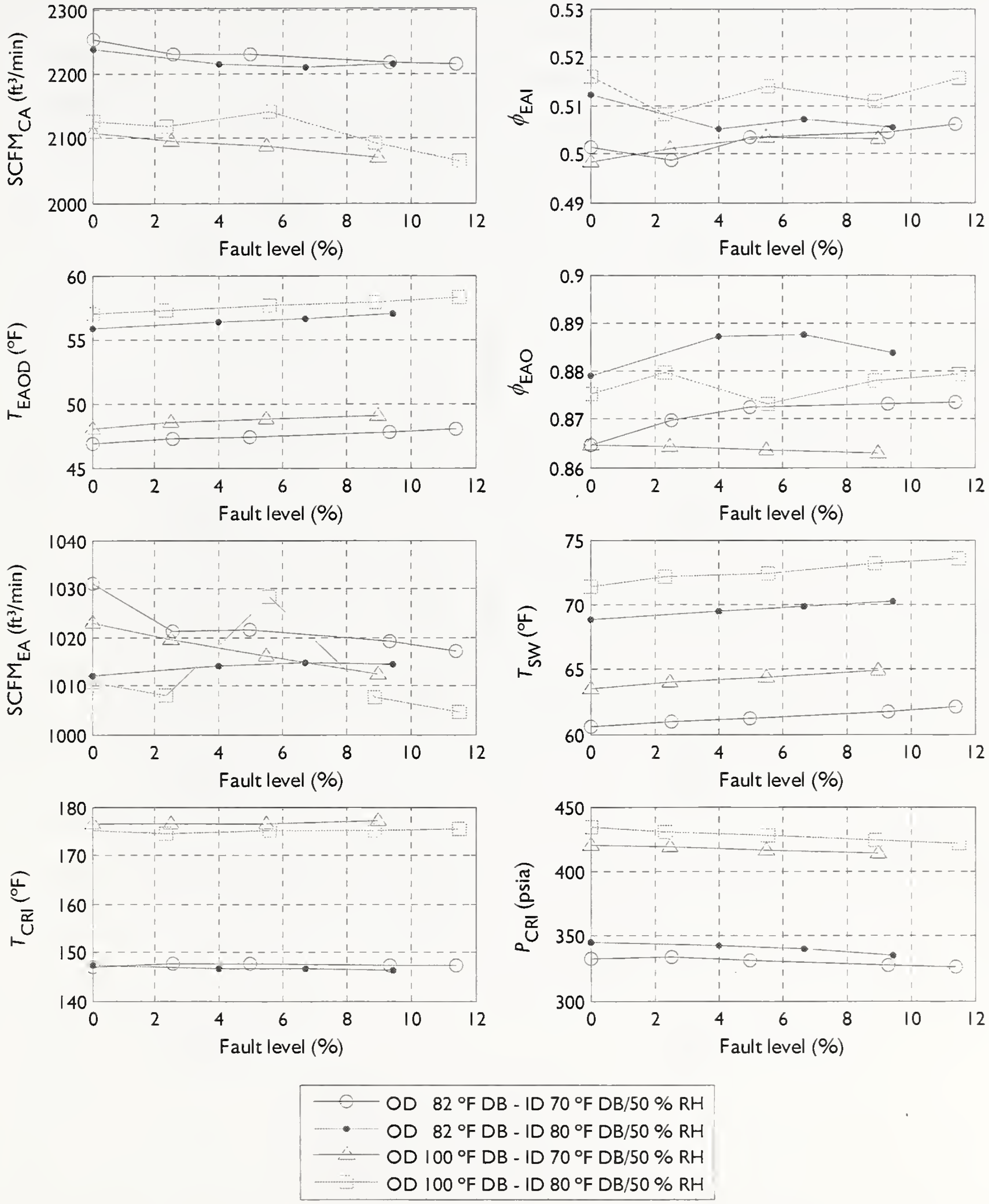

Figure C.3. Selected parameters with the compressor/reversing valve leakage fault. From the top left to right: $SCFM_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, $SCFM_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

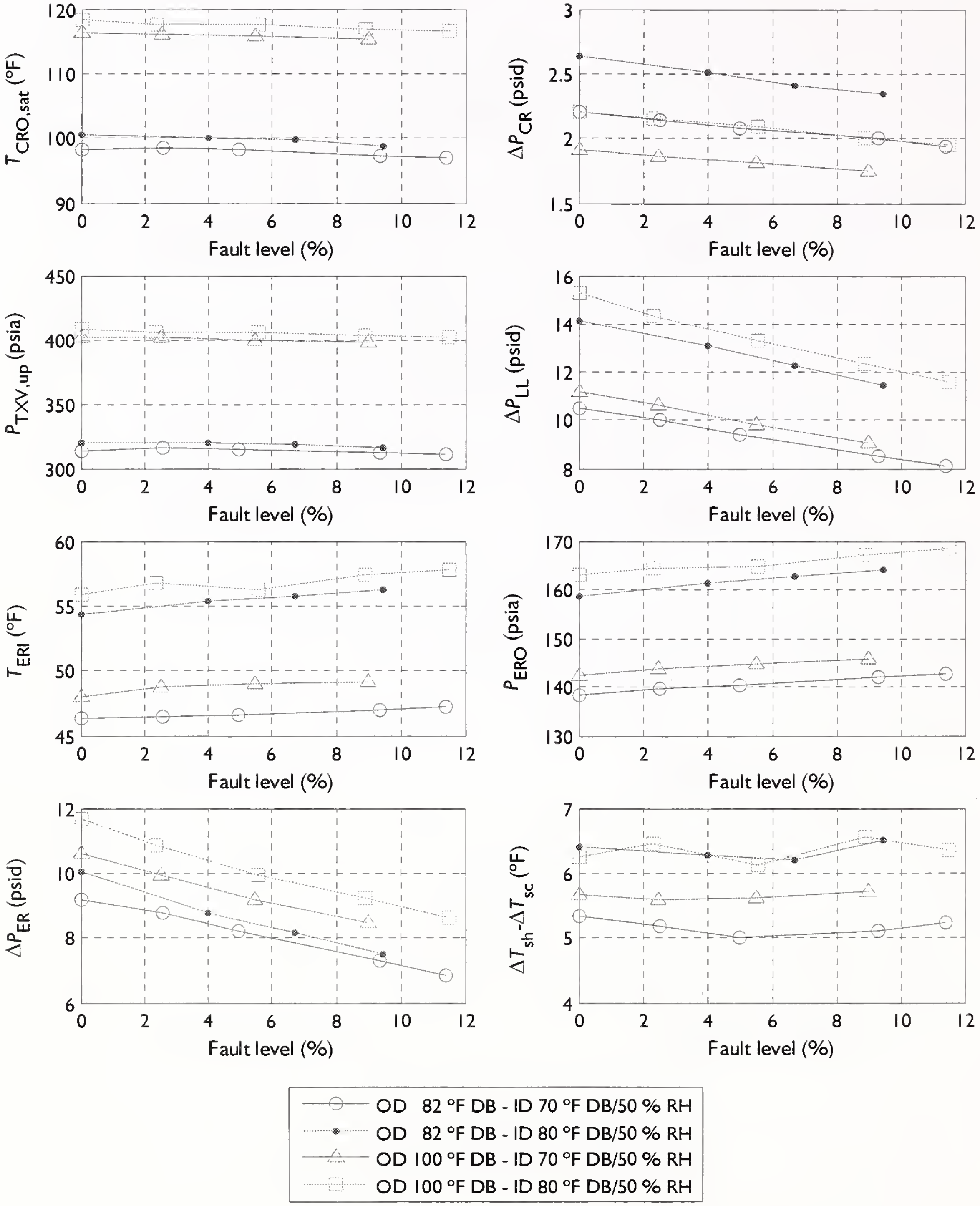

Figure C.4. Selected parameters with the compressor/reversing valve leakage fault. From the top left to right: $T_{\mathrm{CRO,sat}}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{\mathrm{TXV,up}}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{\mathrm{sh}} - \Delta T_{\mathrm{sc}}$

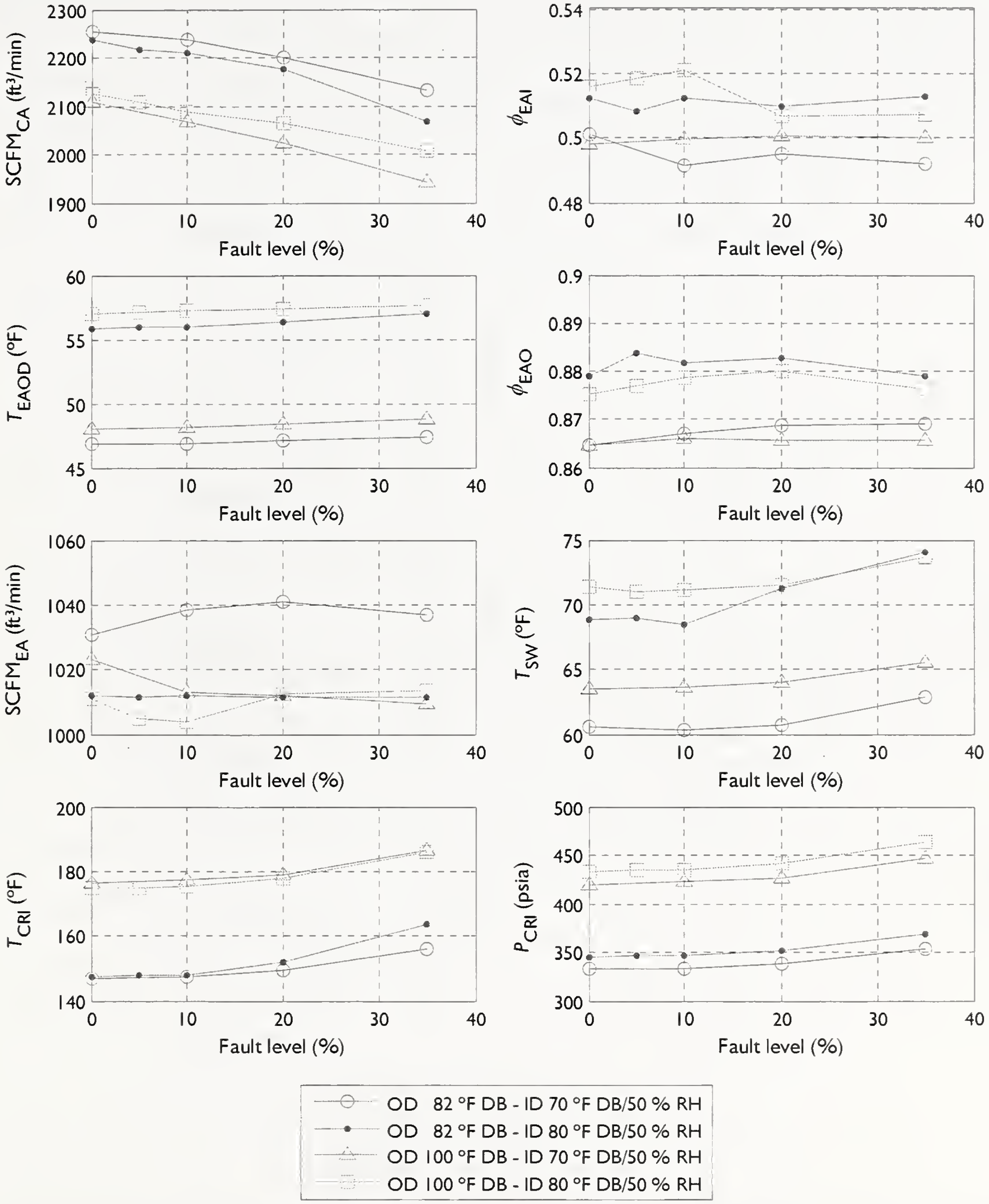

Figure C.5. Selected parameters with the improper outdoor flow rate fault. From the top left to right: SCFM$_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, SCFM$_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

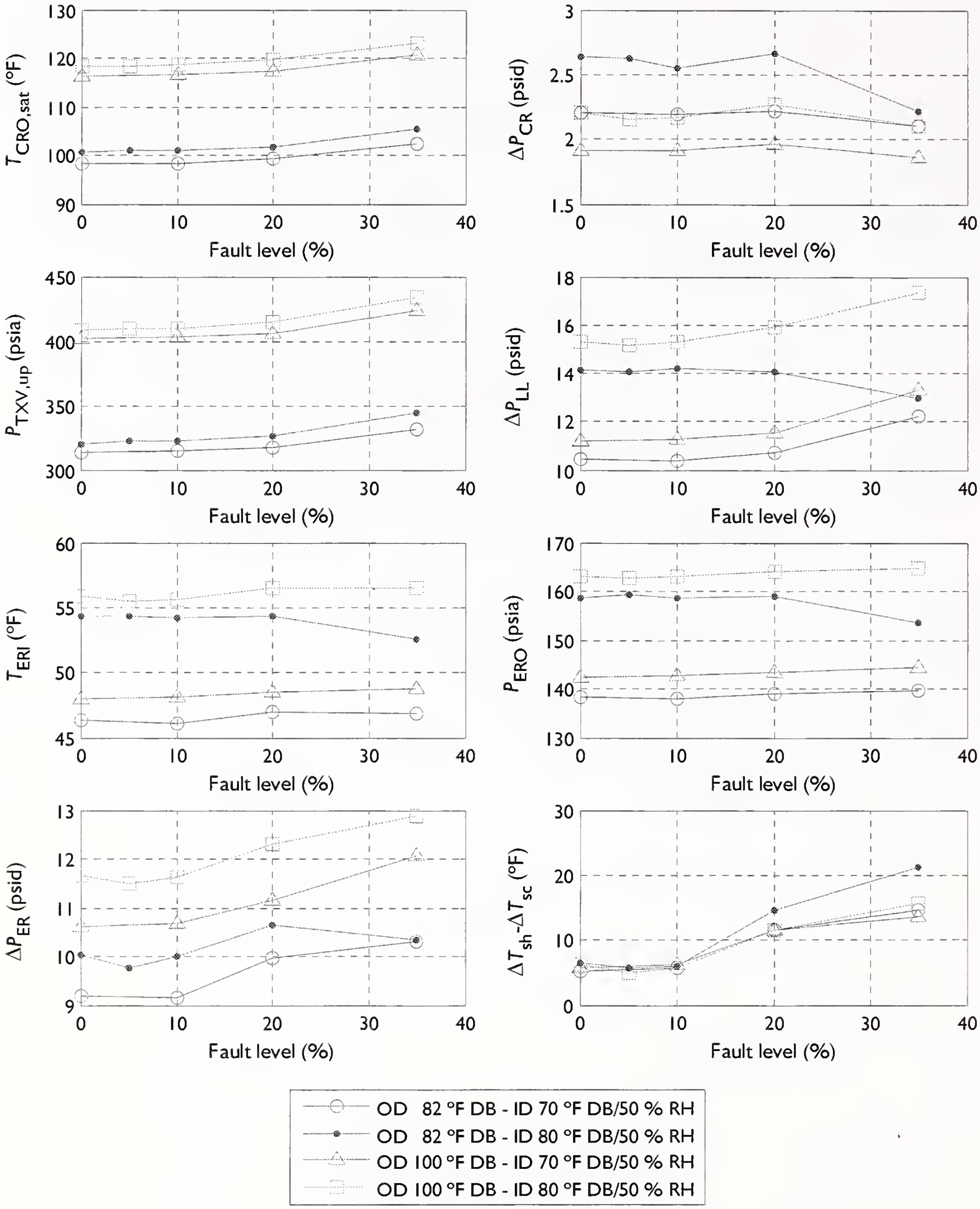

Figure C.6. Selected parameters with the improper outdoor flow rate fault. From the top left to right: $T_{CRO,sat}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{TXV,up}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{sh} - \Delta T_{sc}$

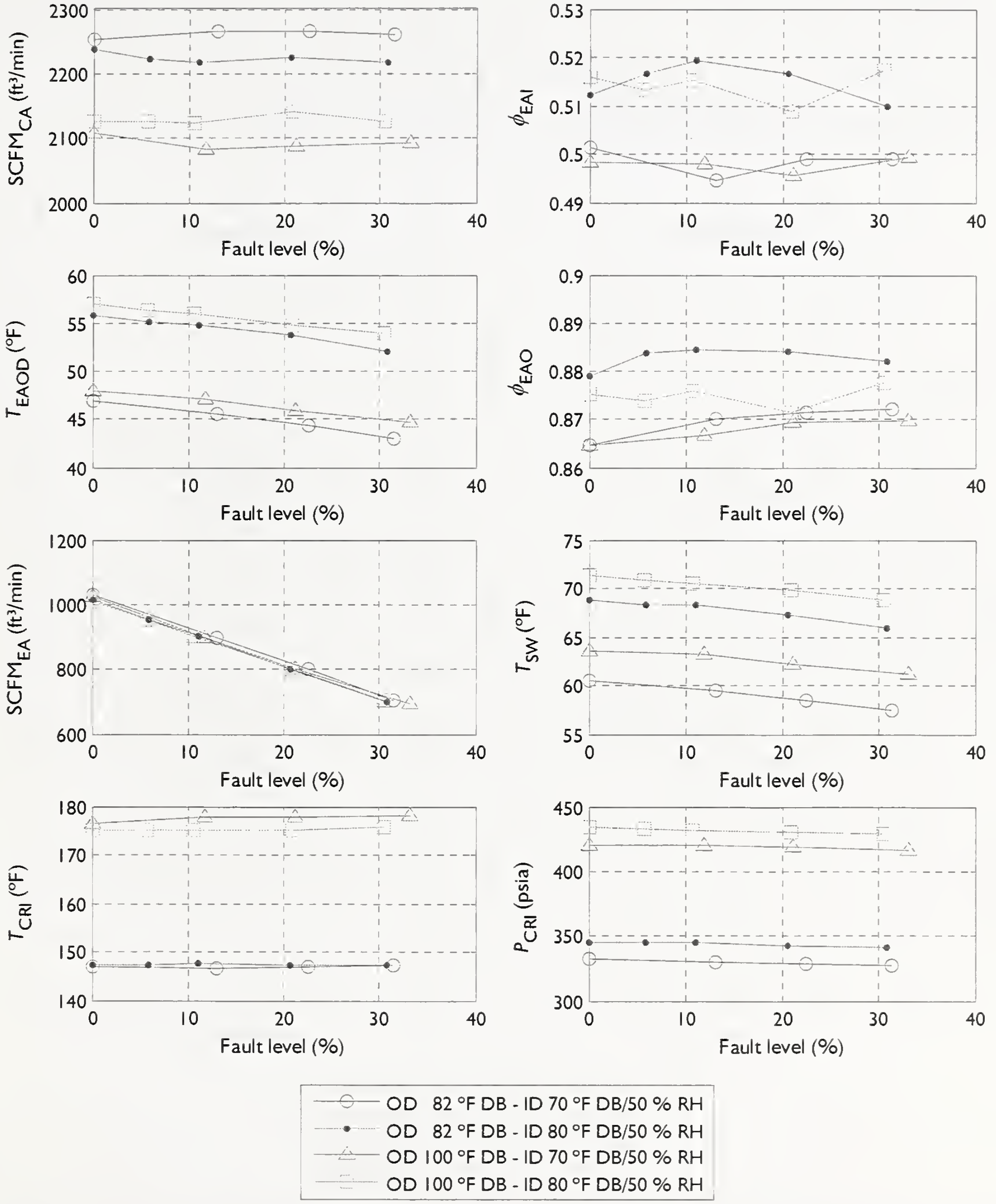

Figure C.7. Selected parameters with the improper indoor flow rate fault. From the top left to right: $SCFM_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, $SCFM_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

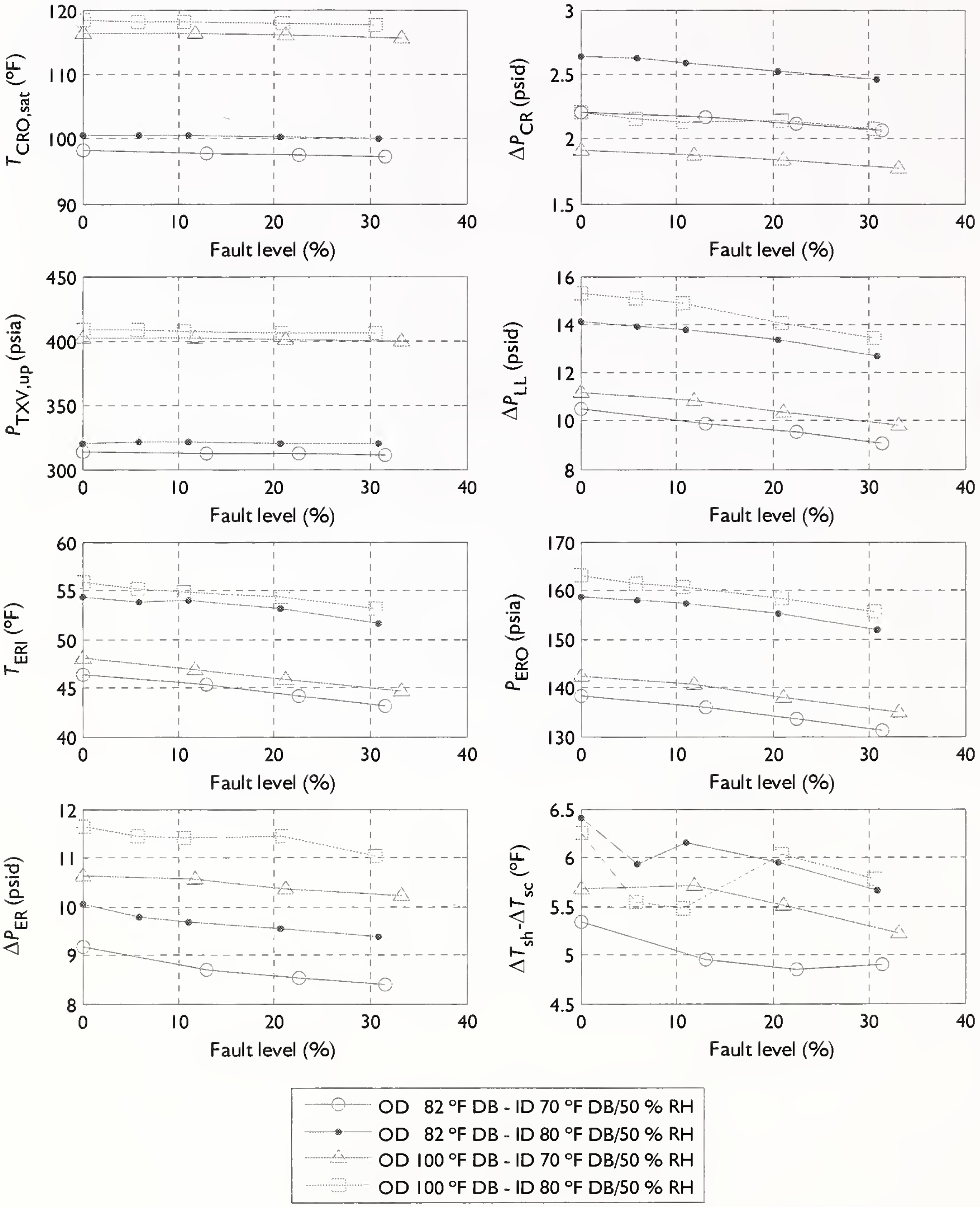

Figure C.8. Selected parameters with the improper indoor flow rate fault. From the top left to right: $T_{CRO,sat}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{TXV,up}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{sh} - \Delta T_{sc}$

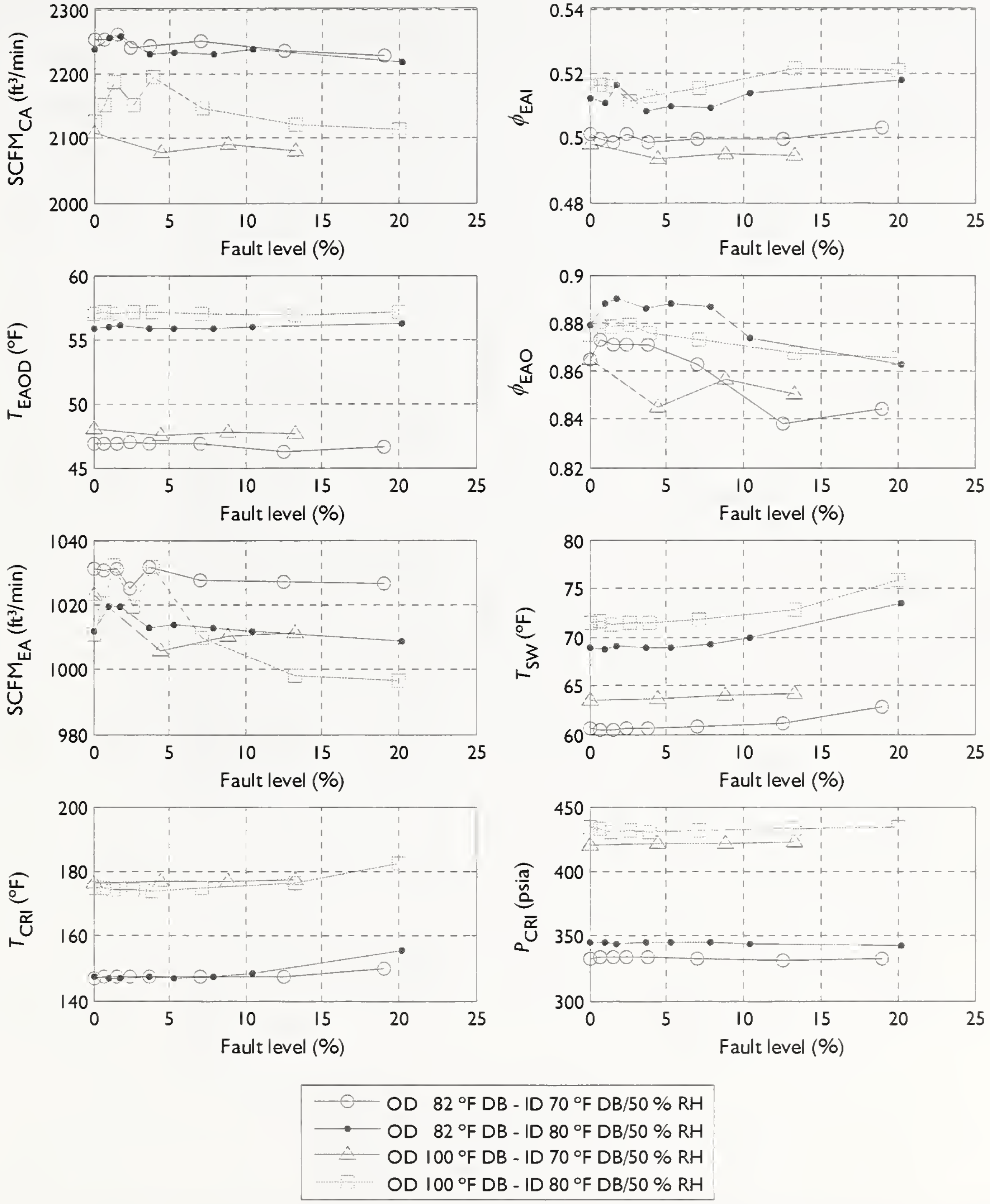

Figure C.9. Selected parameters with the liquid line restriction fault. From the top left to right: SCFM$_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, SCFM$_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

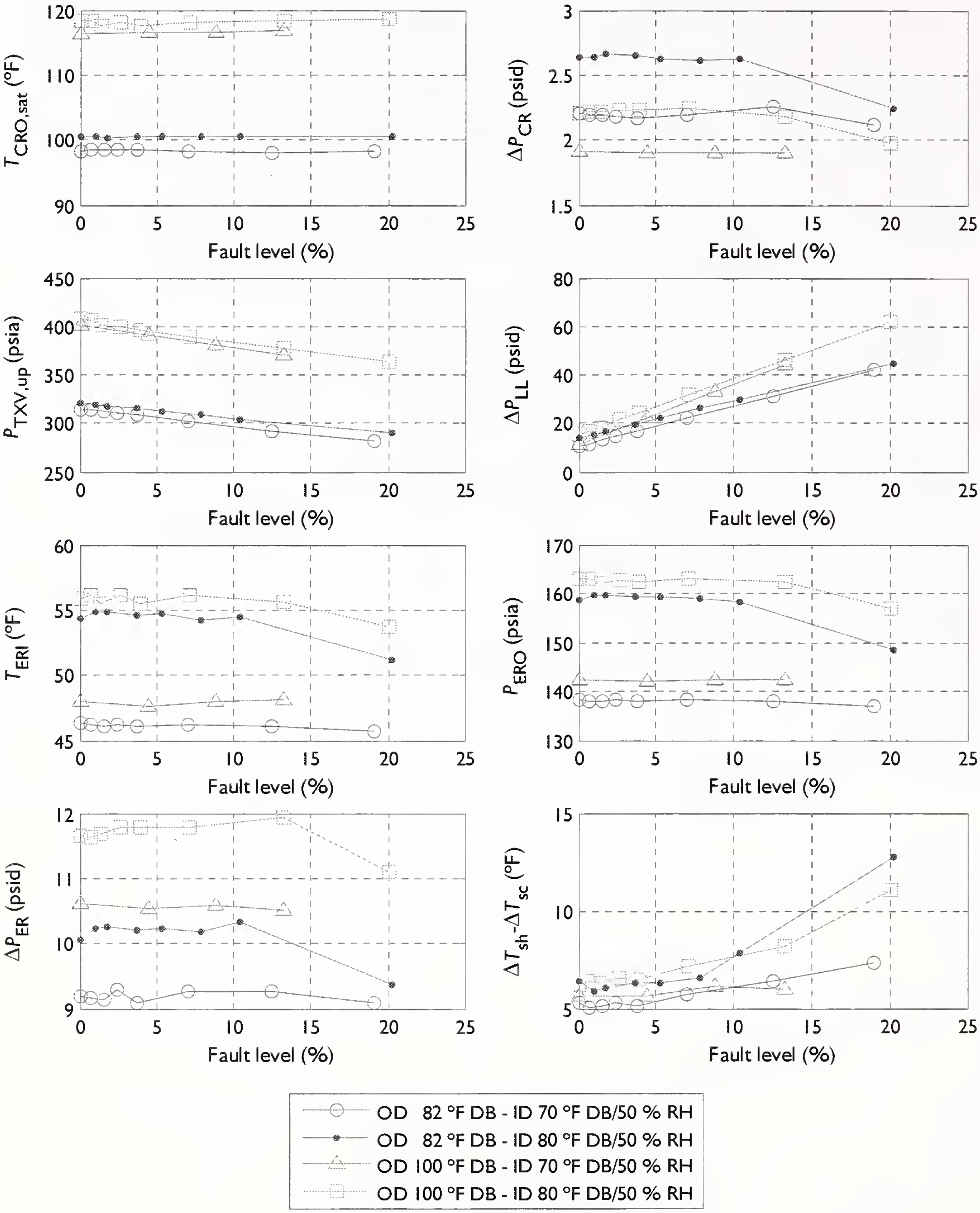

Figure C.10. Selected parameters with the liquid line restriction fault. From the top left to right: $T_{\mathrm{CRO,sat}}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{\mathrm{TXV,up}}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{\mathrm{sh}} - \Delta T_{\mathrm{sc}}$

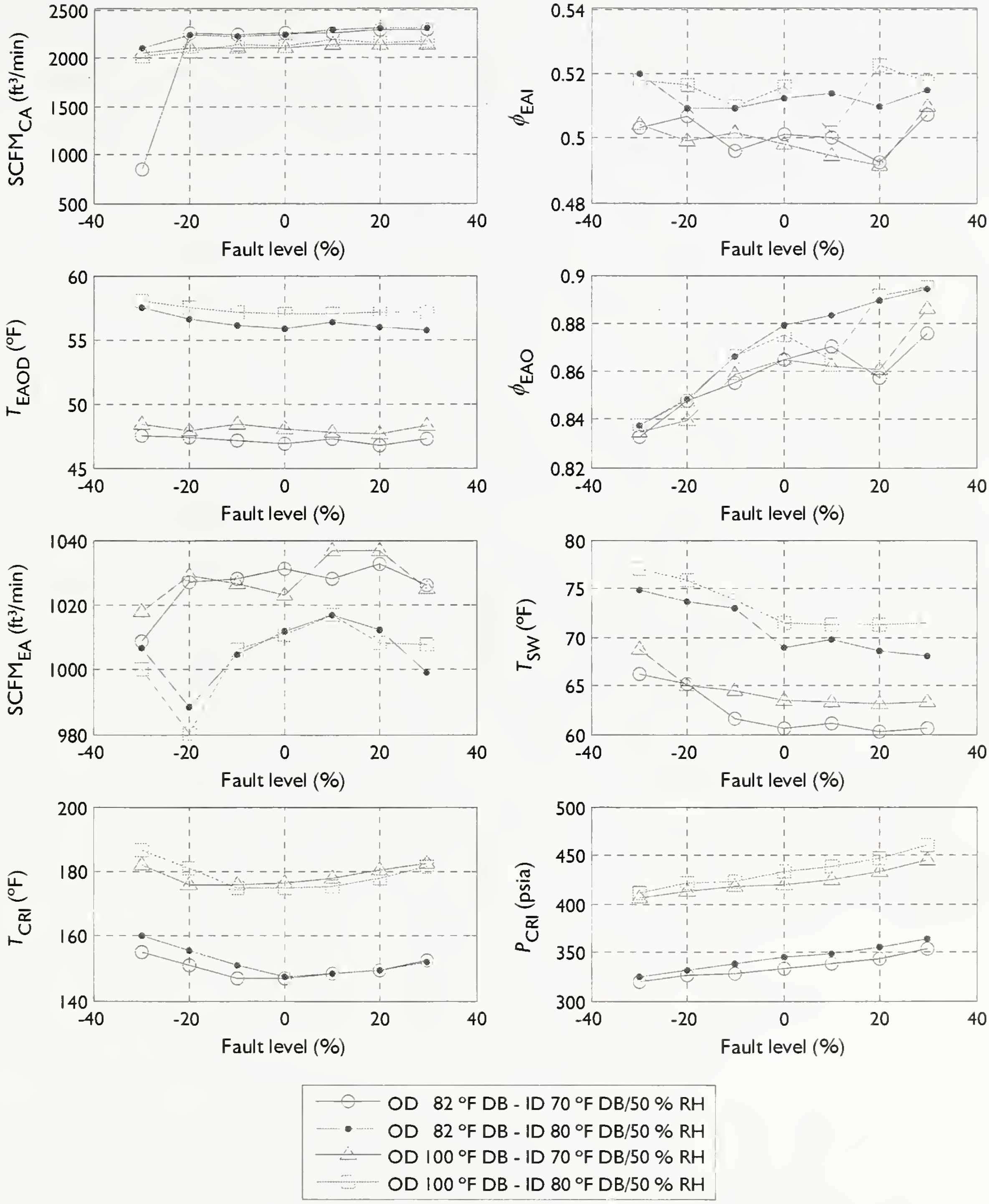

Figure C.11. Selected parameters with the refrigerant undercharge/overcharge fault. From the top left to right: SCFM$_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, SCFM$_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

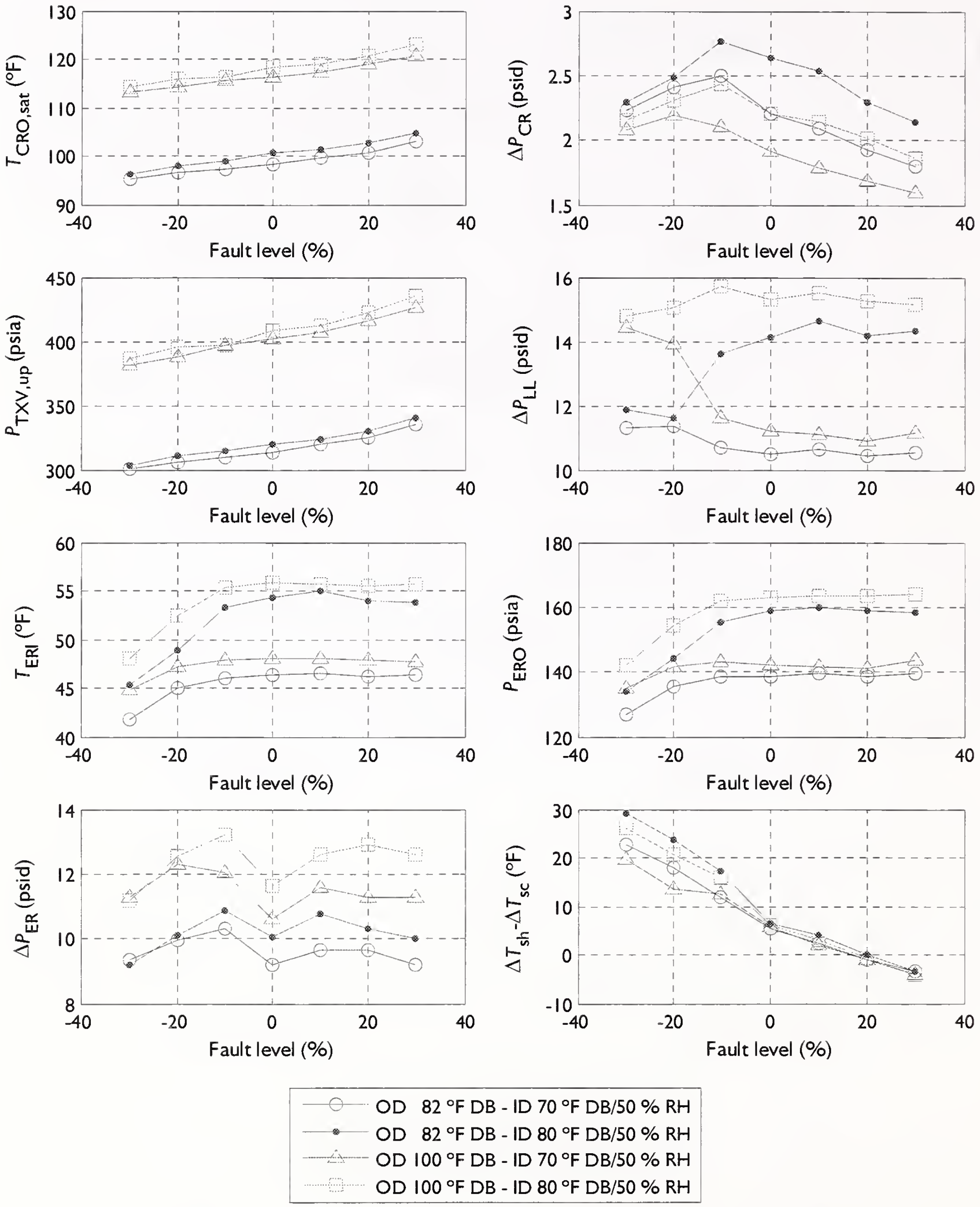

Figure C.12. Selected parameters with the refrigerant undercharge/overcharge fault. From the top left to right: $T_{CRO,sat}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{TXV,up}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{sh} - \Delta T_{sc}$

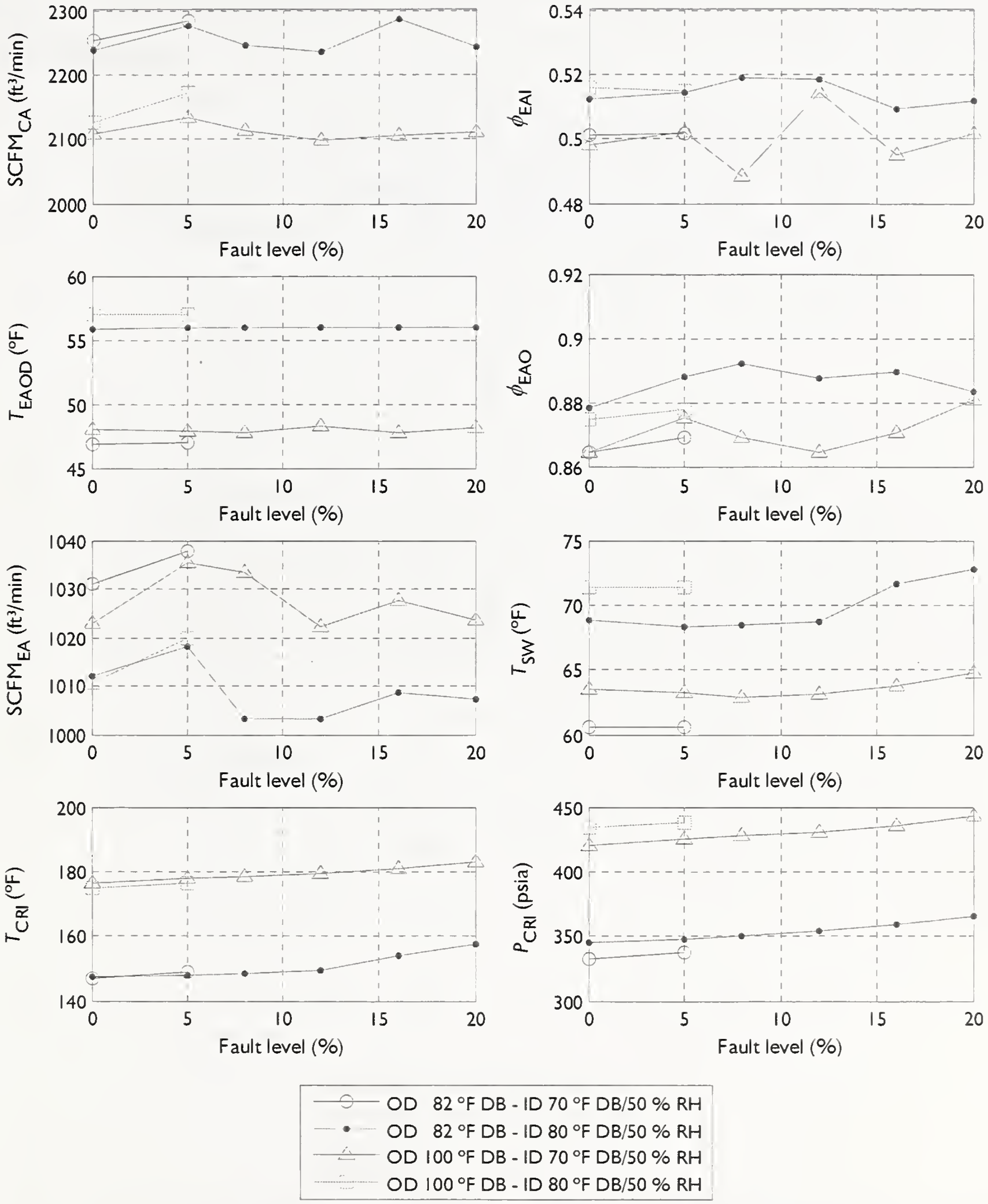

Figure C.13. Selected parameters with the non-condensable gas fault. From the top left to right: SCFM$_{CA}$ – outdoor air flow rate, ϕ_{EAI} – indoor air inlet relative humidity, T_{EAOD} – indoor air exit dew point temperature, ϕ_{EAO} – indoor air exit relative humidity, SCFM$_{EA}$ – indoor air flow rate, T_{SW} – compressor suction wall temperature, T_{CRI} – condenser refrigerant inlet temperature, P_{CRI} – condenser refrigerant inlet pressure

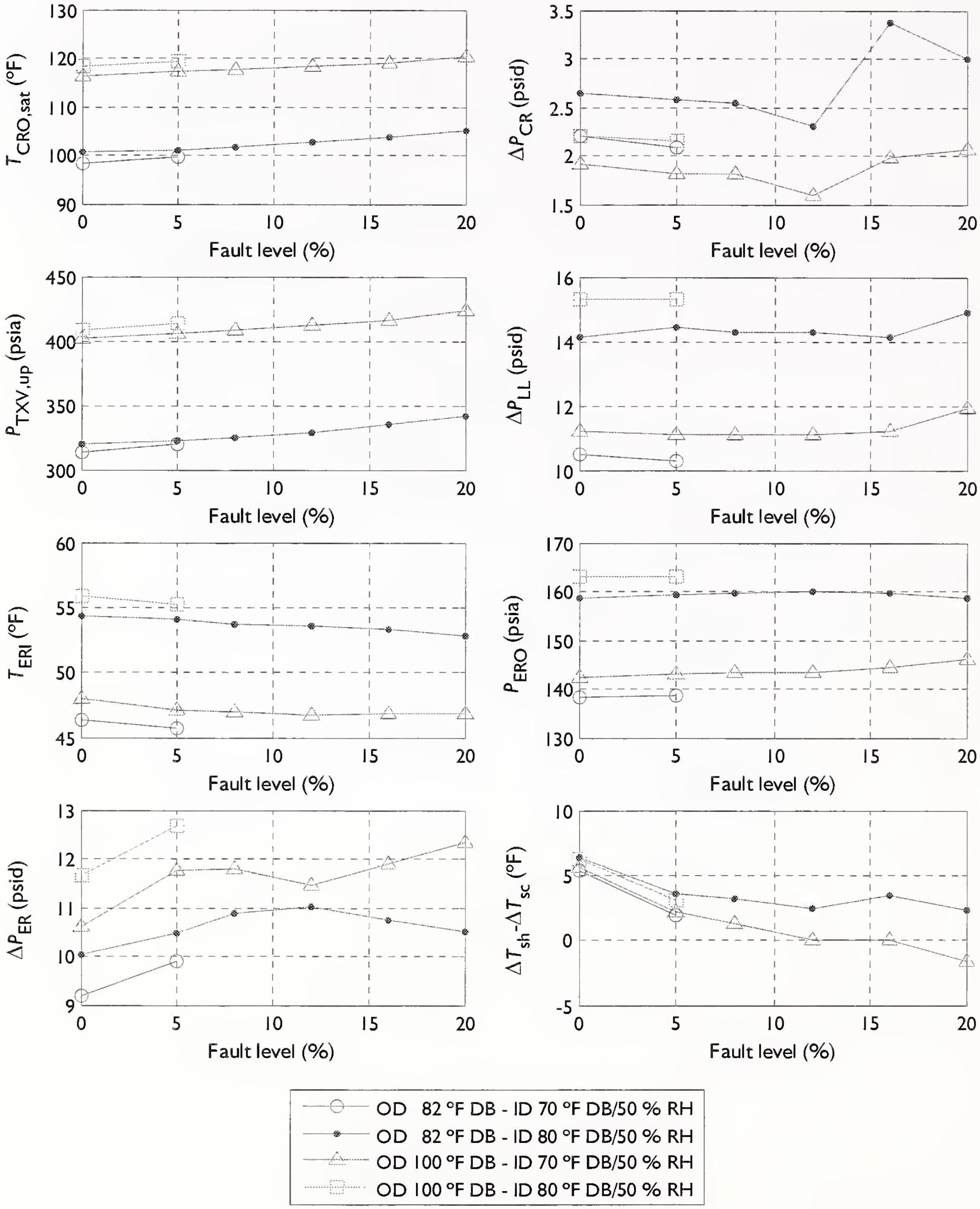

Figure C.14. Selected parameters with the non-condensable gas fault. From the top left to right: $T_{CRO,sat}$ – condenser refrigerant exit saturation temperature, ΔP_{CR} – condenser refrigerant pressure drop, $P_{TXV,up}$ – TXV upstream pressure, ΔP_{LL} – liquid line pressure drop; T_{ERI} – evaporator refrigerant inlet temperature, P_{ERO} – evaporator refrigerant exit pressure, ΔP_{ER} – evaporator refrigerant pressure drop, $\Delta T_{sh} - \Delta T_{sc}$

APPENDIX D. RAW EXPERIMENTAL DATA[1]

D.1 No-Fault Tests

Table D.1. List of raw data for no-fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
2	70	50	70	NF	0.0
3	80	50	70	NF	0.0
4	70	50	82	NF	0.0
5	80	50	82	NF	0.0
6	70	50	90	NF	0.0
7	80	50	90	NF	0.0
8	70	50	100	NF	0.0
9	80	50	100	NF	0.0
10	70	dry	70	NF	0.0
11	80	dry	70	NF	0.0
12	70	dry	82	NF	0.0
13	80	dry	82	NF	0.0
14	70	dry	90	NF	0.0
15	80	dry	90	NF	0.0
16	70	dry	100	NF	0.0
17	80	dry	100	NF	0.0

---

[1] Data listed here was averaged from the repetition tests with the same nominal condition.

```
          HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 02
             FAULT TYPE: NO-FAULT
              FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.69
  Indoor Dry-Bulb Temperature (°F):    70.29
 Indoor Dew-Point Temperature (°F):    50.27
 Outdoor Dry-Bulb Temperature (°F):    69.69
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.29
  Inlet Dew-Point Temperature (°F):    50.27
    Exit Dry-Bulb Temperature (°F):    49.88
   Exit Dew-Point Temperature (°F):    46.57
       Inlet Relative Humidity (-):    0.490
        Exit Relative Humidity (-):    0.883
    Evaporator Coil Temp Drop (°F):    20.41
              Air Flow Rate (SCFM):   1043.6
         Fan Power Consumption (W):   431.35
(OUTDOOR UNIT)
             Inlet Temperature (°F):   69.69
              Exit Temperature (°F):   84.54
    Condensing Unit Temp Gain (°F):    14.86
         Fan Power Consumption (W):   164.47
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4893.5
         Sensible Capacity (Btu/h):  23297.5
          Overall Capacity (Btu/h):  28191.0
           Sensible Heat Ratio (-):    0.826
     Overall Power Consumption (W):   2063.0
         NET Cooling EER (Btu/h.W):    13.67
   Evaporator Energy Imbalance (%):     3.41
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):   45.44
              Exit Temperature (°F):   55.54
              Inlet Pressure (psia):  144.06
               Exit Pressure (psia):  136.44
               Pressure Drop (psid):    7.62
                Exit Superheat (°F):   13.96
        Exit Sat. Temperature (°F):    41.58
       Evaporator Capacity (Btu/h):  29633.9
(CONDENSER)
             Inlet Temperature (°F):  129.56
              Exit Temperature (°F):   76.81
              Inlet Pressure (psia):  281.62
               Exit Pressure (psia):  279.11
               Pressure Drop (psid):    2.51
               Exit Subcooling (°F):    8.24
       Inlet Sat. Temperature (°F):    88.41
        Condenser Capacity (Btu/h):  35639.9
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   77.86
         Cond Unit Exit Pres (psia):  273.34
      Liq-line Pressure Drop (psid):    9.93
       TXV Upstream Pressure (psia):  263.42
           TXV Pressure Drop (psid):  119.35
              Temperature Drop (°F):    0.62
(COMPRESSOR)
           Suction Temperature (°F):   59.01
         Discharge Temperature (°F):  133.51
            Suction Pressure (psia):  134.17
          Discharge Pressure (psia):  282.75
           Discharge Superheat (°F):   45.10
        Comp Bottom Shell Temp (°F):   99.75
             Mass Flow Rate (lbm/h):  378.63
         Comp Power Consumption (W):  1467.1
          Cond Unit Inlet Temp (°F):   57.28
        Cond Unit Inlet Pres (psia):  135.49
```

```
          HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 03
             FAULT TYPE: NO-FAULT
              FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.63
  Indoor Dry-Bulb Temperature (°F):    80.12
 Indoor Dew-Point Temperature (°F):    60.49
 Outdoor Dry-Bulb Temperature (°F):    69.96
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.12
  Inlet Dew-Point Temperature (°F):    60.49
    Exit Dry-Bulb Temperature (°F):    58.74
   Exit Dew-Point Temperature (°F):    55.71
       Inlet Relative Humidity (-):    0.512
        Exit Relative Humidity (-):    0.896
    Evaporator Coil Temp Drop (°F):    21.38
              Air Flow Rate (SCFM):   1019.6
         Fan Power Consumption (W):   419.70
(OUTDOOR UNIT)
             Inlet Temperature (°F):   69.96
              Exit Temperature (°F):   87.16
    Condensing Unit Temp Gain (°F):    17.20
         Fan Power Consumption (W):   163.05
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   8542.0
         Sensible Capacity (Btu/h):  23978.2
          Overall Capacity (Btu/h):  32520.3
           Sensible Heat Ratio (-):    0.737
     Overall Power Consumption (W):   2089.8
         NET Cooling EER (Btu/h.W):    15.56
   Evaporator Energy Imbalance (%):     3.99
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):   53.51
              Exit Temperature (°F):   68.14
              Inlet Pressure (psia):  164.06
               Exit Pressure (psia):  155.47
               Pressure Drop (psid):    8.60
                Exit Superheat (°F):   18.73
        Exit Sat. Temperature (°F):    49.41
       Evaporator Capacity (Btu/h):  34307.5
(CONDENSER)
             Inlet Temperature (°F):  133.88
              Exit Temperature (°F):   77.85
              Inlet Pressure (psia):  294.52
               Exit Pressure (psia):  291.65
               Pressure Drop (psid):    2.87
               Exit Subcooling (°F):   10.15
       Inlet Sat. Temperature (°F):    91.57
        Condenser Capacity (Btu/h):  40243.2
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   78.81
         Cond Unit Exit Pres (psia):  284.72
      Liq-line Pressure Drop (psid):   12.81
       TXV Upstream Pressure (psia):  271.91
           TXV Pressure Drop (psid):  107.85
              Temperature Drop (°F):    0.19
(COMPRESSOR)
           Suction Temperature (°F):   69.92
         Discharge Temperature (°F):  137.42
            Suction Pressure (psia):  152.95
          Discharge Pressure (psia):  295.95
           Discharge Superheat (°F):   45.78
        Comp Bottom Shell Temp (°F):  104.81
             Mass Flow Rate (lbm/h):  427.24
         Comp Power Consumption (W):  1507.0
          Cond Unit Inlet Temp (°F):   69.09
        Cond Unit Inlet Pres (psia):  154.24
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.35
  Indoor Dry-Bulb Temperature (°F):     69.87
 Indoor Dew-Point Temperature (°F):     50.47
 Outdoor Dry-Bulb Temperature (°F):     81.73
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.87
  Inlet Dew-Point Temperature (°F):     50.47
    Exit Dry-Bulb Temperature (°F):     50.73
   Exit Dew-Point Temperature (°F):     47.15
       Inlet Relative Humidity (-):     0.501
        Exit Relative Humidity (-):     0.875
    Evaporator Coil Temp Drop (°F):     19.14
              Air Flow Rate (SCFM):    1030.9
         Fan Power Consumption (W):    425.01
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.73
               Exit Temperature (°F):   96.67
    Condensing Unit Temp Gain (°F):     14.94
         Fan Power Consumption (W):    159.78
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   4455.9
          Sensible Capacity (Btu/h):  21596.0
           Overall Capacity (Btu/h):  26051.8
            Sensible Heat Ratio (-):    0.829
     Overall Power Consumption (W):    2276.8
          NET Cooling EER (Btu/h.W):    11.44
    Evaporator Energy Imbalance (%):     4.08
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   46.30
               Exit Temperature (°F):   55.65
              Inlet Pressure (psia):   147.59
               Exit Pressure (psia):   138.41
               Pressure Drop (psid):     9.18
                 Exit Superheat (°F):   13.22
         Exit Sat. Temperature (°F):    42.43
        Evaporator Capacity (Btu/h):  27602.0
(CONDENSER)
              Inlet Temperature (°F):  147.04
               Exit Temperature (°F):   89.79
              Inlet Pressure (psia):   332.63
               Exit Pressure (psia):   330.42
               Pressure Drop (psid):     2.21
               Exit Subcooling (°F):     7.89
        Inlet Sat. Temperature (°F):   100.35
         Condenser Capacity (Btu/h):  34588.4
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    90.44
         Cond Unit Exit Pres (psia):   324.50
      Liq-line Pressure Drop (psid):    10.47
       TXV Upstream Pressure (psia):   314.03
           TXV Pressure Drop (psid):   166.44
              Temperature Drop (°F):     0.94
(COMPRESSOR)
           Suction Temperature (°F):    60.53
         Discharge Temperature (°F):   151.47
            Suction Pressure (psia):   136.16
          Discharge Pressure (psia):   333.65
           Discharge Superheat (°F):    51.16
        Comp Bottom Shell Temp (°F):   108.08
            Mass Flow Rate (lbm/h):   377.89
         Comp Power Consumption (W):   1692.0
          Cond Unit Inlet Temp (°F):    57.80
        Cond Unit Inlet Pres (psia):   137.45
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 05
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.42
  Indoor Dry-Bulb Temperature (°F):     80.00
 Indoor Dew-Point Temperature (°F):     60.38
 Outdoor Dry-Bulb Temperature (°F):     81.76
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.00
  Inlet Dew-Point Temperature (°F):     60.38
    Exit Dry-Bulb Temperature (°F):     59.45
   Exit Dew-Point Temperature (°F):     56.16
       Inlet Relative Humidity (-):     0.512
        Exit Relative Humidity (-):     0.888
    Evaporator Coil Temp Drop (°F):     20.55
              Air Flow Rate (SCFM):    1011.9
         Fan Power Consumption (W):    417.19
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.76
               Exit Temperature (°F):   98.97
    Condensing Unit Temp Gain (°F):     17.21
         Fan Power Consumption (W):    159.70
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   7574.1
          Sensible Capacity (Btu/h):  22880.0
           Overall Capacity (Btu/h):  30454.2
            Sensible Heat Ratio (-):    0.751
     Overall Power Consumption (W):    2334.6
          NET Cooling EER (Btu/h.W):    13.05
    Evaporator Energy Imbalance (%):     4.30
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   54.33
               Exit Temperature (°F):   65.66
              Inlet Pressure (psia):   168.84
               Exit Pressure (psia):   158.78
               Pressure Drop (psid):    10.05
                 Exit Superheat (°F):   14.96
         Exit Sat. Temperature (°F):    50.71
        Evaporator Capacity (Btu/h):  32257.1
(CONDENSER)
              Inlet Temperature (°F):  147.23
               Exit Temperature (°F):   90.77
              Inlet Pressure (psia):   344.71
               Exit Pressure (psia):   342.08
               Pressure Drop (psid):     2.64
               Exit Subcooling (°F):     8.55
        Inlet Sat. Temperature (°F):   102.97
         Condenser Capacity (Btu/h):  39257.0
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    92.01
         Cond Unit Exit Pres (psia):   334.55
      Liq-line Pressure Drop (psid):    14.14
       TXV Upstream Pressure (psia):   320.41
           TXV Pressure Drop (psid):   151.58
              Temperature Drop (°F):     0.63
(COMPRESSOR)
           Suction Temperature (°F):    68.82
         Discharge Temperature (°F):   150.92
            Suction Pressure (psia):   156.32
          Discharge Pressure (psia):   345.92
           Discharge Superheat (°F):    47.96
        Comp Bottom Shell Temp (°F):   109.48
            Mass Flow Rate (lbm/h):   435.58
         Comp Power Consumption (W):   1757.7
          Cond Unit Inlet Temp (°F):    67.15
        Cond Unit Inlet Pres (psia):   157.57
```

```
          HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 06
             FAULT TYPE: NO-FAULT
              FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.68
   Indoor Dry-Bulb Temperature (°F):    69.84
  Indoor Dew-Point Temperature (°F):    50.29
  Outdoor Dry-Bulb Temperature (°F):    90.03
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    69.84
   Inlet Dew-Point Temperature (°F):    50.29
     Exit Dry-Bulb Temperature (°F):    50.92
    Exit Dew-Point Temperature (°F):    47.59
        Inlet Relative Humidity (-):    0.498
         Exit Relative Humidity (-):    0.883
     Evaporator Coil Temp Drop (°F):    18.93
              Air Flow Rate (SCFM):    1041.5
         Fan Power Consumption (W):    429.06
(OUTDOOR UNIT)
              Inlet Temperature (°F):   90.03
               Exit Temperature (°F):  104.76
     Condensing Unit Temp Gain (°F):    14.73
         Fan Power Consumption (W):    159.61
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3632.5
         Sensible Capacity (Btu/h):   21574.1
          Overall Capacity (Btu/h):   25206.5
           Sensible Heat Ratio (-):     0.856
     Overall Power Consumption (W):    2516.9
         NET Cooling EER (Btu/h.W):     10.02
    Evaporator Energy Imbalance (%):     1.90
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   47.03
               Exit Temperature (°F):   55.89
                Inlet Pressure (psia):  149.74
                 Exit Pressure (psia):  140.11
                 Pressure Drop (psid):    9.63
                  Exit Superheat (°F):   12.73
           Exit Sat. Temperature (°F):   43.16
        Evaporator Capacity (Btu/h):  26132.9
(CONDENSER)
              Inlet Temperature (°F):  159.88
               Exit Temperature (°F):   98.38
                Inlet Pressure (psia):  370.75
                 Exit Pressure (psia):  368.71
                 Pressure Drop (psid):    2.04
                 Exit Subcooling (°F):    7.65
          Inlet Sat. Temperature (°F):  108.38
         Condenser Capacity (Btu/h):  33921.2
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    98.84
         Cond Unit Exit Pres (psia):   362.52
      Liq-line Pressure Drop (psid):    10.68
       TXV Upstream Pressure (psia):   351.85
           TXV Pressure Drop (psid):   202.10
               Temperature Drop (°F):    1.28
(COMPRESSOR)
           Suction Temperature (°F):    61.75
         Discharge Temperature (°F):   164.74
           Suction Pressure (psia):    137.97
         Discharge Pressure (psia):    371.68
           Discharge Superheat (°F):    56.42
         Comp Bottom Shell Temp (°F):  115.57
              Mass Flow Rate (lbm/h):  376.74
         Comp Power Consumption (W):   1928.2
           Cond Unit Inlet Temp (°F):   58.41
         Cond Unit Inlet Pres (psia):  139.24
```

```
          HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 07
             FAULT TYPE: NO-FAULT
              FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.35
   Indoor Dry-Bulb Temperature (°F):    79.97
  Indoor Dew-Point Temperature (°F):    60.84
  Outdoor Dry-Bulb Temperature (°F):    89.95
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    79.97
   Inlet Dew-Point Temperature (°F):    60.84
     Exit Dry-Bulb Temperature (°F):    59.76
    Exit Dew-Point Temperature (°F):    56.86
        Inlet Relative Humidity (-):    0.521
         Exit Relative Humidity (-):    0.901
     Evaporator Coil Temp Drop (°F):    20.21
              Air Flow Rate (SCFM):    1008.6
         Fan Power Consumption (W):    416.91
(OUTDOOR UNIT)
              Inlet Temperature (°F):   89.95
               Exit Temperature (°F):  107.28
     Condensing Unit Temp Gain (°F):    17.33
         Fan Power Consumption (W):    157.98
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    7266.5
         Sensible Capacity (Btu/h):   22444.3
          Overall Capacity (Btu/h):   29710.8
           Sensible Heat Ratio (-):     0.755
     Overall Power Consumption (W):    2540.5
         NET Cooling EER (Btu/h.W):     11.70
    Evaporator Energy Imbalance (%):     2.67
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   55.27
               Exit Temperature (°F):   66.05
                Inlet Pressure (psia):  173.22
                 Exit Pressure (psia):  161.98
                 Pressure Drop (psid):   11.24
                  Exit Superheat (°F):   14.12
           Exit Sat. Temperature (°F):   51.93
        Evaporator Capacity (Btu/h):  30955.0
(CONDENSER)
              Inlet Temperature (°F):  158.87
               Exit Temperature (°F):   99.28
                Inlet Pressure (psia):  384.20
                 Exit Pressure (psia):  381.75
                 Pressure Drop (psid):    2.45
                 Exit Subcooling (°F):    8.29
          Inlet Sat. Temperature (°F):  111.07
         Condenser Capacity (Btu/h):  38794.1
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   100.53
         Cond Unit Exit Pres (psia):   373.92
      Liq-line Pressure Drop (psid):    14.63
       TXV Upstream Pressure (psia):   359.29
           TXV Pressure Drop (psid):   186.07
               Temperature Drop (°F):    0.84
(COMPRESSOR)
           Suction Temperature (°F):    69.92
         Discharge Temperature (°F):   162.88
           Suction Pressure (psia):    159.47
         Discharge Pressure (psia):    385.52
           Discharge Superheat (°F):    51.80
         Comp Bottom Shell Temp (°F):  115.29
              Mass Flow Rate (lbm/h):  440.16
         Comp Power Consumption (W):   1965.6
           Cond Unit Inlet Temp (°F):   67.68
         Cond Unit Inlet Pres (psia):  160.73
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 08
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.17
  Indoor Dry-Bulb Temperature (°F):     69.96
 Indoor Dew-Point Temperature (°F):     50.40
 Outdoor Dry-Bulb Temperature (°F):     99.92
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.96
  Inlet Dew-Point Temperature (°F):     50.40
    Exit Dry-Bulb Temperature (°F):     51.88
   Exit Dew-Point Temperature (°F):     48.28
       Inlet Relative Humidity (-):     0.498
        Exit Relative Humidity (-):     0.875
    Evaporator Coil Temp Drop (°F):     18.09
              Air Flow Rate (SCFM):    1023.0
          Fan Power Consumption (W):   421.35
(OUTDOOR UNIT)
               Inlet Temperature (°F):  99.92
                Exit Temperature (°F): 114.81
    Condensing Unit Temp Gain (°F):     14.89
          Fan Power Consumption (W):   155.77
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   2884.0
          Sensible Capacity (Btu/h):  20253.5
           Overall Capacity (Btu/h):  23137.5
             Sensible Heat Ratio (-):   0.875
      Overall Power Consumption (W):   2778.5
        NET Cooling EER (Btu/h.W):       8.33
   Evaporator Energy Imbalance (%):      3.07
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):  48.03
                Exit Temperature (°F):  56.61
               Inlet Pressure (psia):  152.98
                Exit Pressure (psia):  142.36
                Pressure Drop (psid):   10.62
                 Exit Superheat (°F):   12.51
          Exit Sat. Temperature (°F):   44.10
        Evaporator Capacity (Btu/h):  24305.6
(CONDENSER)
               Inlet Temperature (°F): 176.41
                Exit Temperature (°F): 109.39
               Inlet Pressure (psia):  420.23
                Exit Pressure (psia):  418.32
                Pressure Drop (psid):    1.91
                Exit Subcooling (°F):    6.84
         Inlet Sat. Temperature (°F):  117.91
         Condenser Capacity (Btu/h):  33119.3
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   109.44
         Cond Unit Exit Pres (psia):   412.50
       Liq-line Pressure Drop (psid):   11.18
        TXV Upstream Pressure (psia):  401.32
            TXV Pressure Drop (psid):  248.34
                Temperature Drop (°F):   1.40
(COMPRESSOR)
            Suction Temperature (°F):   63.55
         Discharge Temperature (°F):   181.89
             Suction Pressure (psia):  140.18
           Discharge Pressure (psia):  421.36
            Discharge Superheat (°F):   64.00
         Comp Bottom Shell Temp (°F):  126.54
              Mass Flow Rate (lbm/h):  375.25
         Comp Power Consumption (W):   2201.3
           Cond Unit Inlet Temp (°F):   59.30
         Cond Unit Inlet Pres (psia):  141.41
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 09
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.44
  Indoor Dry-Bulb Temperature (°F):     79.99
 Indoor Dew-Point Temperature (°F):     60.58
 Outdoor Dry-Bulb Temperature (°F):     99.97
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.99
  Inlet Dew-Point Temperature (°F):     60.58
    Exit Dry-Bulb Temperature (°F):     60.77
   Exit Dew-Point Temperature (°F):     57.35
       Inlet Relative Humidity (-):     0.516
        Exit Relative Humidity (-):     0.885
    Evaporator Coil Temp Drop (°F):     19.22
              Air Flow Rate (SCFM):    1010.7
          Fan Power Consumption (W):   418.57
(OUTDOOR UNIT)
               Inlet Temperature (°F):  99.97
                Exit Temperature (°F): 116.88
    Condensing Unit Temp Gain (°F):     16.91
          Fan Power Consumption (W):   156.68
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   5927.3
          Sensible Capacity (Btu/h):  21382.4
           Overall Capacity (Btu/h):  27309.7
             Sensible Heat Ratio (-):   0.783
      Overall Power Consumption (W):   2825.1
        NET Cooling EER (Btu/h.W):       9.67
   Evaporator Energy Imbalance (%):      2.86
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):  55.87
                Exit Temperature (°F):  66.41
               Inlet Pressure (psia):  174.60
                Exit Pressure (psia):  162.94
                Pressure Drop (psid):   11.66
                 Exit Superheat (°F):   14.12
          Exit Sat. Temperature (°F):   52.29
        Evaporator Capacity (Btu/h):  28544.8
(CONDENSER)
               Inlet Temperature (°F): 174.98
                Exit Temperature (°F): 109.75
               Inlet Pressure (psia):  433.61
                Exit Pressure (psia):  431.41
                Pressure Drop (psid):    2.21
                Exit Subcooling (°F):    7.86
         Inlet Sat. Temperature (°F):  120.33
         Condenser Capacity (Btu/h):  37455.2
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   110.48
         Cond Unit Exit Pres (psia):   423.64
       Liq-line Pressure Drop (psid):   15.28
        TXV Upstream Pressure (psia):  408.36
            TXV Pressure Drop (psid):  233.76
                Temperature Drop (°F):   1.00
(COMPRESSOR)
            Suction Temperature (°F):   71.38
         Discharge Temperature (°F):   179.35
             Suction Pressure (psia):  160.65
           Discharge Pressure (psia):  434.60
            Discharge Superheat (°F):   59.06
         Comp Bottom Shell Temp (°F):  125.47
              Mass Flow Rate (lbm/h):  433.15
         Comp Power Consumption (W):   2249.9
           Cond Unit Inlet Temp (°F):   68.44
         Cond Unit Inlet Pres (psia):  161.83
        HEAT PUMP FAULT TEST SUMMARY

      INDOOR/OUTDOOR CONDITION #: 10
           FAULT TYPE: NO-FAULT
            FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.85
   Indoor Dry-Bulb Temperature (°F):    69.92
  Indoor Dew-Point Temperature (°F):    32.01
  Outdoor Dry-Bulb Temperature (°F):    69.91
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    69.92
   Inlet Dew-Point Temperature (°F):    32.01
     Exit Dry-Bulb Temperature (°F):    46.40
    Exit Dew-Point Temperature (°F):    32.15
        Inlet Relative Humidity (-):    0.245
         Exit Relative Humidity (-):    0.573
     Evaporator Coil Temp Drop (°F):    23.52
               Air Flow Rate (SCFM):   1066.7
          Fan Power Consumption (W):   440.33
(OUTDOOR UNIT)
             Inlet Temperature (°F):    69.91
              Exit Temperature (°F):    83.82
     Condensing Unit Temp Gain (°F):    13.91
          Fan Power Consumption (W):   166.38
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):      0.0
          Sensible Capacity (Btu/h):  27277.5
           Overall Capacity (Btu/h):  27167.6
            Sensible Heat Ratio (-):    1.000
      Overall Power Consumption (W):   2067.9
          NET Cooling EER (Btu/h.W):    13.14
    Evaporator Energy Imbalance (%):    -0.20
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    43.57
              Exit Temperature (°F):    51.39
              Inlet Pressure (psia):   136.13
               Exit Pressure (psia):   128.45
               Pressure Drop (psid):     7.68
                Exit Superheat (°F):    13.35
         Exit Sat. Temperature (°F):    38.05
        Evaporator Capacity (Btu/h):  27552.1
(CONDENSER)
             Inlet Temperature (°F):   129.87
              Exit Temperature (°F):    76.96
              Inlet Pressure (psia):   277.97
               Exit Pressure (psia):   275.68
               Pressure Drop (psid):     2.29
               Exit Subcooling (°F):     7.84
        Inlet Sat. Temperature (°F):    87.49
         Condenser Capacity (Btu/h):  33602.5
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):  77.55
           Cond Unit Exit Pres (psia): 270.63
         Liq-line Pressure Drop (psid):  8.76
          TXV Upstream Pressure (psia): 261.87
              TXV Pressure Drop (psid): 125.74
                 Temperature Drop (°F):   0.59
(COMPRESSOR)
           Suction Temperature (°F):    55.73
         Discharge Temperature (°F):   134.22
            Suction Pressure (psia):   126.18
          Discharge Pressure (psia):   278.91
           Discharge Superheat (°F):    46.76
        Comp Bottom Shell Temp (°F):    99.65
             Mass Flow Rate (lbm/h):   355.07
         Comp Power Consumption (W):   1461.2
           Cond Unit Inlet Temp (°F):   53.48
        Cond Unit Inlet Pres (psia):   127.53
```

```
        HEAT PUMP FAULT TEST SUMMARY

      INDOOR/OUTDOOR CONDITION #: 11
           FAULT TYPE: NO-FAULT
            FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.77
   Indoor Dry-Bulb Temperature (°F):    80.28
  Indoor Dew-Point Temperature (°F):    32.01
  Outdoor Dry-Bulb Temperature (°F):    69.77
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    80.28
   Inlet Dew-Point Temperature (°F):    32.01
     Exit Dry-Bulb Temperature (°F):    53.31
    Exit Dew-Point Temperature (°F):    32.10
        Inlet Relative Humidity (-):    0.173
         Exit Relative Humidity (-):    0.442
     Evaporator Coil Temp Drop (°F):    26.97
               Air Flow Rate (SCFM):   1045.8
          Fan Power Consumption (W):   434.65
(OUTDOOR UNIT)
             Inlet Temperature (°F):    69.77
              Exit Temperature (°F):    85.22
     Condensing Unit Temp Gain (°F):    15.45
          Fan Power Consumption (W):   164.81
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):      0.0
          Sensible Capacity (Btu/h):  30670.9
           Overall Capacity (Btu/h):  30602.3
            Sensible Heat Ratio (-):    1.000
      Overall Power Consumption (W):   2074.2
          NET Cooling EER (Btu/h.W):    14.75
    Evaporator Energy Imbalance (%):     0.91
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    49.98
              Exit Temperature (°F):    59.86
              Inlet Pressure (psia):   151.33
               Exit Pressure (psia):   143.19
               Pressure Drop (psid):     8.14
                Exit Superheat (°F):    15.41
         Exit Sat. Temperature (°F):    44.45
        Evaporator Capacity (Btu/h):  31320.6
(CONDENSER)
             Inlet Temperature (°F):   130.53
              Exit Temperature (°F):    77.40
              Inlet Pressure (psia):   285.19
               Exit Pressure (psia):   282.54
               Pressure Drop (psid):     2.65
               Exit Subcooling (°F):     8.16
        Inlet Sat. Temperature (°F):    89.29
         Condenser Capacity (Btu/h):  37331.2
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):  78.70
           Cond Unit Exit Pres (psia): 276.34
         Liq-line Pressure Drop (psid): 11.33
          TXV Upstream Pressure (psia): 265.02
              TXV Pressure Drop (psid): 113.69
                 Temperature Drop (°F):   0.24
(COMPRESSOR)
           Suction Temperature (°F):    62.67
         Discharge Temperature (°F):   134.21
            Suction Pressure (psia):   140.77
          Discharge Pressure (psia):   285.79
           Discharge Superheat (°F):    45.04
        Comp Bottom Shell Temp (°F):   101.14
             Mass Flow Rate (lbm/h):   397.99
         Comp Power Consumption (W):   1474.7
           Cond Unit Inlet Temp (°F):   61.43
        Cond Unit Inlet Pres (psia):   142.08
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 12
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.68
  Indoor Dry-Bulb Temperature (°F):     70.20
 Indoor Dew-Point Temperature (°F):     32.01
 Outdoor Dry-Bulb Temperature (°F):     81.91
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.20
  Inlet Dew-Point Temperature (°F):     32.01
    Exit Dry-Bulb Temperature (°F):     47.51
   Exit Dew-Point Temperature (°F):     32.14
       Inlet Relative Humidity (-):     0.242
        Exit Relative Humidity (-):     0.549
    Evaporator Coil Temp Drop (°F):     22.70
              Air Flow Rate (SCFM):    1055.1
        Fan Power Consumption (W):     434.44
(OUTDOOR UNIT)
             Inlet Temperature (°F):     81.91
              Exit Temperature (°F):     95.98
    Condensing Unit Temp Gain (°F):     14.07
        Fan Power Consumption (W):     161.76
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):       0.0
         Sensible Capacity (Btu/h):   26038.7
          Overall Capacity (Btu/h):   25939.0
           Sensible Heat Ratio (-):     1.000
     Overall Power Consumption (W):    2312.2
        NET Cooling EER (Btu/h.W):     11.22
   Evaporator Energy Imbalance (%):     -1.51
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     45.07
             Exit Temperature (°F):     52.55
              Inlet Pressure (psia):   141.05
               Exit Pressure (psia):   132.29
               Pressure Drop (psid):     8.75
                Exit Superheat (°F):    12.78
        Exit Sat. Temperature (°F):     39.77
      Evaporator Capacity (Btu/h):   25981.6
(CONDENSER)
            Inlet Temperature (°F):    147.58
             Exit Temperature (°F):     89.91
              Inlet Pressure (psia):   329.20
               Exit Pressure (psia):   327.10
               Pressure Drop (psid):     2.10
               Exit Subcooling (°F):     7.43
       Inlet Sat. Temperature (°F):     99.59
       Condenser Capacity (Btu/h):   32989.5
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):     90.25
         Cond Unit Exit Pres (psia):   321.64
     Liq-line Pressure Drop (psid):     9.40
      TXV Upstream Pressure (psia):   312.24
          TXV Pressure Drop (psid):   171.19
              Temperature Drop (°F):     0.99
(COMPRESSOR)
          Suction Temperature (°F):     58.13
        Discharge Temperature (°F):    152.42
           Suction Pressure (psia):   130.01
         Discharge Pressure (psia):   330.06
          Discharge Superheat (°F):     52.91
       Comp Bottom Shell Temp (°F):    108.50
            Mass Flow Rate (lbm/h):    358.40
       Comp Power Consumption (W):    1716.0
          Cond Unit Inlet Temp (°F):     55.02
       Cond Unit Inlet Pres (psia):    131.33
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 13
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.90
  Indoor Dry-Bulb Temperature (°F):     80.23
 Indoor Dew-Point Temperature (°F):     35.65
 Outdoor Dry-Bulb Temperature (°F):     81.83
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.23
  Inlet Dew-Point Temperature (°F):     35.65
    Exit Dry-Bulb Temperature (°F):     54.02
   Exit Dew-Point Temperature (°F):     36.13
       Inlet Relative Humidity (-):     0.201
        Exit Relative Humidity (-):     0.506
    Evaporator Coil Temp Drop (°F):     26.22
              Air Flow Rate (SCFM):    1014.9
        Fan Power Consumption (W):     424.00
(OUTDOOR UNIT)
             Inlet Temperature (°F):     81.83
              Exit Temperature (°F):     97.67
    Condensing Unit Temp Gain (°F):     15.84
        Fan Power Consumption (W):     159.79
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):       0.0
         Sensible Capacity (Btu/h):   28969.4
          Overall Capacity (Btu/h):   28564.2
           Sensible Heat Ratio (-):     1.000
     Overall Power Consumption (W):    2325.4
        NET Cooling EER (Btu/h.W):     12.28
   Evaporator Energy Imbalance (%):      0.27
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     51.06
             Exit Temperature (°F):     59.66
              Inlet Pressure (psia):   155.32
               Exit Pressure (psia):   145.94
               Pressure Drop (psid):     9.37
                Exit Superheat (°F):    14.07
        Exit Sat. Temperature (°F):     45.59
      Evaporator Capacity (Btu/h):   29065.5
(CONDENSER)
            Inlet Temperature (°F):    147.97
             Exit Temperature (°F):     90.37
              Inlet Pressure (psia):   338.02
               Exit Pressure (psia):   335.67
               Pressure Drop (psid):     2.35
               Exit Subcooling (°F):     7.92
       Inlet Sat. Temperature (°F):    101.53
       Condenser Capacity (Btu/h):   36092.7
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):     91.45
         Cond Unit Exit Pres (psia):   329.15
     Liq-line Pressure Drop (psid):    11.77
      TXV Upstream Pressure (psia):   317.39
          TXV Pressure Drop (psid):   162.07
              Temperature Drop (°F):     0.62
(COMPRESSOR)
          Suction Temperature (°F):     64.05
        Discharge Temperature (°F):    151.99
           Suction Pressure (psia):   143.53
         Discharge Pressure (psia):   338.56
          Discharge Superheat (°F):     50.61
       Comp Bottom Shell Temp (°F):    109.54
            Mass Flow Rate (lbm/h):    396.63
       Comp Power Consumption (W):    1741.6
          Cond Unit Inlet Temp (°F):     61.80
       Cond Unit Inlet Pres (psia):    144.83
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 14
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.54
  Indoor Dry-Bulb Temperature (°F):     70.05
 Indoor Dew-Point Temperature (°F):     32.01
 Outdoor Dry-Bulb Temperature (°F):     89.86
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.05
  Inlet Dew-Point Temperature (°F):     32.01
    Exit Dry-Bulb Temperature (°F):     48.07
   Exit Dew-Point Temperature (°F):     32.39
       Inlet Relative Humidity (-):     0.244
        Exit Relative Humidity (-):     0.543
    Evaporator Coil Temp Drop (°F):     21.97
              Air Flow Rate (SCFM):    1050.2
         Fan Power Consumption (W):    433.00
(OUTDOOR UNIT)
             Inlet Temperature (°F):     89.86
              Exit Temperature (°F):    104.06
    Condensing Unit Temp Gain (°F):     14.20
         Fan Power Consumption (W):    159.67
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):       0.0
         Sensible Capacity (Btu/h):   25094.2
          Overall Capacity (Btu/h):   24803.3
           Sensible Heat Ratio (-):     1.000
     Overall Power Consumption (W):    2508.1
        NET Cooling EER (Btu/h.W):      9.89
   Evaporator Energy Imbalance (%):     -1.61
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     45.87
              Exit Temperature (°F):     53.32
              Inlet Pressure (psia):    144.01
               Exit Pressure (psia):    134.57
               Pressure Drop (psid):      9.45
                Exit Superheat (°F):     12.56
       Exit Sat. Temperature (°F):      40.77
      Evaporator Capacity (Btu/h):   24837.2
(CONDENSER)
             Inlet Temperature (°F):    160.26
              Exit Temperature (°F):     98.62
              Inlet Pressure (psia):    366.24
               Exit Pressure (psia):    364.29
               Pressure Drop (psid):      1.95
               Exit Subcooling (°F):      7.03
      Inlet Sat. Temperature (°F):     107.47
       Condenser Capacity (Btu/h):   32599.7
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     98.64
        Cond Unit Exit Pres (psia):    358.56
     Liq-line Pressure Drop (psid):      9.72
     TXV Upstream Pressure (psia):     348.84
          TXV Pressure Drop (psid):    204.83
              Temperature Drop (°F):      1.28
(COMPRESSOR)
           Suction Temperature (°F):     59.80
         Discharge Temperature (°F):    165.53
            Suction Pressure (psia):    132.28
          Discharge Pressure (psia):    367.01
           Discharge Superheat (°F):     58.16
       Comp Bottom Shell Temp (°F):    116.03
             Mass Flow Rate (lbm/h):    360.01
        Comp Power Consumption (W):    1915.4
           Cond Unit Inlet Temp (°F):     56.08
       Cond Unit Inlet Pres (psia):    133.60
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 15
              FAULT TYPE: NO-FAULT
               FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.93
  Indoor Dry-Bulb Temperature (°F):     79.94
 Indoor Dew-Point Temperature (°F):     36.88
 Outdoor Dry-Bulb Temperature (°F):     90.09
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.94
  Inlet Dew-Point Temperature (°F):     36.88
    Exit Dry-Bulb Temperature (°F):     54.75
   Exit Dew-Point Temperature (°F):     37.43
       Inlet Relative Humidity (-):     0.213
        Exit Relative Humidity (-):     0.519
    Evaporator Coil Temp Drop (°F):     25.18
              Air Flow Rate (SCFM):    1014.9
         Fan Power Consumption (W):    423.29
(OUTDOOR UNIT)
             Inlet Temperature (°F):     90.09
              Exit Temperature (°F):    105.95
    Condensing Unit Temp Gain (°F):     15.86
         Fan Power Consumption (W):    157.67
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):       0.0
         Sensible Capacity (Btu/h):   27840.8
          Overall Capacity (Btu/h):   27354.4
           Sensible Heat Ratio (-):     1.000
     Overall Power Consumption (W):    2529.5
        NET Cooling EER (Btu/h.W):     10.81
   Evaporator Energy Imbalance (%):      0.16
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     51.87
              Exit Temperature (°F):     60.19
              Inlet Pressure (psia):    158.68
               Exit Pressure (psia):    148.44
               Pressure Drop (psid):     10.24
                Exit Superheat (°F):     13.58
       Exit Sat. Temperature (°F):      46.61
      Evaporator Capacity (Btu/h):   27821.6
(CONDENSER)
             Inlet Temperature (°F):    160.34
              Exit Temperature (°F):     99.25
              Inlet Pressure (psia):    376.95
               Exit Pressure (psia):    374.78
               Pressure Drop (psid):      2.17
               Exit Subcooling (°F):      7.68
      Inlet Sat. Temperature (°F):     109.63
       Condenser Capacity (Btu/h):   35658.4
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     99.96
        Cond Unit Exit Pres (psia):    368.14
     Liq-line Pressure Drop (psid):     12.38
     TXV Upstream Pressure (psia):     355.76
          TXV Pressure Drop (psid):    197.08
              Temperature Drop (°F):      0.85
(COMPRESSOR)
           Suction Temperature (°F):     65.49
         Discharge Temperature (°F):    164.71
            Suction Pressure (psia):    146.08
          Discharge Pressure (psia):    377.53
           Discharge Superheat (°F):     55.22
       Comp Bottom Shell Temp (°F):    116.03
             Mass Flow Rate (lbm/h):    399.48
        Comp Power Consumption (W):    1948.5
           Cond Unit Inlet Temp (°F):     62.60
       Cond Unit Inlet Pres (psia):    147.36
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 16
             FAULT TYPE: NO-FAULT
              FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):      30.39
  Indoor Dry-Bulb Temperature (°F):      70.17
 Indoor Dew-Point Temperature (°F):      32.27
 Outdoor Dry-Bulb Temperature (°F):      99.88
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):      70.17
  Inlet Dew-Point Temperature (°F):      32.27
    Exit Dry-Bulb Temperature (°F):      49.57
   Exit Dew-Point Temperature (°F):      32.66
       Inlet Relative Humidity (-):      0.245
        Exit Relative Humidity (-):      0.519
    Evaporator Coil Temp Drop (°F):      20.59
              Air Flow Rate (SCFM):     1042.4
          Fan Power Consumption (W):    429.02
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.88
              Exit Temperature (°F):    114.20
    Condensing Unit Temp Gain (°F):      14.32
          Fan Power Consumption (W):    156.86
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):        0.0
         Sensible Capacity (Btu/h):    23345.2
          Overall Capacity (Btu/h):    23042.1
           Sensible Heat Ratio (-):      1.000
     Overall Power Consumption (W):     2783.3
         NET Cooling EER (Btu/h.W):       8.28
   Evaporator Energy Imbalance (%):      -1.78
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):      46.76
             Exit Temperature (°F):      54.51
             Inlet Pressure (psia):     147.67
              Exit Pressure (psia):     137.21
              Pressure Drop (psid):      10.46
               Exit Superheat (°F):      12.60
        Exit Sat. Temperature (°F):      41.91
       Evaporator Capacity (Btu/h):    23061.9
(CONDENSER)
            Inlet Temperature (°F):     177.67
             Exit Temperature (°F):     109.01
             Inlet Pressure (psia):     416.69
              Exit Pressure (psia):     414.87
              Pressure Drop (psid):       1.82
              Exit Subcooling (°F):       6.56
       Inlet Sat. Temperature (°F):     117.25
        Condenser Capacity (Btu/h):    31823.0
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     109.13
        Cond Unit Exit Pres (psia):     409.36
      Liq-line Pressure Drop (psid):     10.13
       TXV Upstream Pressure (psia):    399.23
          TXV Pressure Drop (psid):     251.56
             Temperature Drop (°F):       1.45
(COMPRESSOR)
          Suction Temperature (°F):      62.20
        Discharge Temperature (°F):     183.41
           Suction Pressure (psia):     135.08
         Discharge Pressure (psia):     417.63
          Discharge Superheat (°F):      66.21
        Comp Bottom Shell Temp (°F):    127.71
             Mass Flow Rate (lbm/h):    357.58
        Comp Power Consumption (W):     2197.4
          Cond Unit Inlet Temp (°F):     57.55
        Cond Unit Inlet Pres (psia):    136.35
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 17
             FAULT TYPE: NO-FAULT
              FAULT LEVEL [%]: 0
RUNNING CONDITIONS
        Barometric Pressure (inHg):      30.73
  Indoor Dry-Bulb Temperature (°F):      80.12
 Indoor Dew-Point Temperature (°F):      32.01
 Outdoor Dry-Bulb Temperature (°F):      99.89
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):      80.12
  Inlet Dew-Point Temperature (°F):      32.01
    Exit Dry-Bulb Temperature (°F):      56.42
   Exit Dew-Point Temperature (°F):      32.14
       Inlet Relative Humidity (-):      0.174
        Exit Relative Humidity (-):      0.396
    Evaporator Coil Temp Drop (°F):      23.70
              Air Flow Rate (SCFM):     1039.5
          Fan Power Consumption (W):    429.64
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.89
              Exit Temperature (°F):    115.61
    Condensing Unit Temp Gain (°F):      15.72
          Fan Power Consumption (W):    158.04
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):        0.0
         Sensible Capacity (Btu/h):    26791.1
          Overall Capacity (Btu/h):    26689.7
           Sensible Heat Ratio (-):      1.000
     Overall Power Consumption (W):     2810.2
         NET Cooling EER (Btu/h.W):       9.50
   Evaporator Energy Imbalance (%):      -2.59
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):      53.56
             Exit Temperature (°F):      61.93
             Inlet Pressure (psia):     164.61
              Exit Pressure (psia):     153.33
              Pressure Drop (psid):      11.28
               Exit Superheat (°F):      13.36
        Exit Sat. Temperature (°F):      48.57
       Evaporator Capacity (Btu/h):    26435.9
(CONDENSER)
            Inlet Temperature (°F):     175.30
             Exit Temperature (°F):     109.51
             Inlet Pressure (psia):     426.19
              Exit Pressure (psia):     424.12
              Pressure Drop (psid):       2.07
              Exit Subcooling (°F):       7.09
       Inlet Sat. Temperature (°F):     118.99
        Condenser Capacity (Btu/h):    35315.5
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     110.07
        Cond Unit Exit Pres (psia):     417.23
      Liq-line Pressure Drop (psid):     13.33
       TXV Upstream Pressure (psia):    403.90
          TXV Pressure Drop (psid):     239.29
             Temperature Drop (°F):       1.04
(COMPRESSOR)
          Suction Temperature (°F):      67.94
        Discharge Temperature (°F):     180.12
           Suction Pressure (psia):     151.01
         Discharge Pressure (psia):     426.83
          Discharge Superheat (°F):      61.23
        Comp Bottom Shell Temp (°F):    125.52
             Mass Flow Rate (lbm/h):    405.02
        Comp Power Consumption (W):     2222.5
          Cond Unit Inlet Temp (°F):     64.43
        Cond Unit Inlet Pres (psia):    152.24
```

D.2 Compressor/Reversing Valve Leakage Fault Tests

Table D.2. List of raw data for compressor/reversing valve leakage fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	CMF	2.5
4	70	50	82	CMF	5.0
4	70	50	82	CMF	9.3
4	70	50	82	CMF	11.4
5	80	50	82	CMF	4.0
5	80	50	82	CMF	6.7
5	80	50	82	CMF	9.5
5	80	50	82	CMF	27.2
5	80	50	82	CMF	38.2
8	70	50	100	CMF	2.5
8	70	50	100	CMF	5.5
8	70	50	100	CMF	9.0
9	80	50	100	CMF	2.4
9	80	50	100	CMF	5.6
9	80	50	100	CMF	8.9
9	80	50	100	CMF	11.5

```
                 HEAT PUMP FAULT TEST SUMMARY

                INDOOR/OUTDOOR CONDITION #: 04
             FAULT TYPE: COMPRESSOR LEAKAGE FAULT
                     FAULT LEVEL [%]: 2.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.06
  Indoor Dry-Bulb Temperature (°F):     70.11
 Indoor Dew-Point Temperature (°F):     50.55
 Outdoor Dry-Bulb Temperature (°F):     82.21
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.11
  Inlet Dew-Point Temperature (°F):     50.55
    Exit Dry-Bulb Temperature (°F):     51.04
   Exit Dew-Point Temperature (°F):     47.61
       Inlet Relative Humidity (-):     0.499
        Exit Relative Humidity (-):     0.880
    Evaporator Coil Temp Drop (°F):     19.07
              Air Flow Rate (SCFM):    1021.0
        Fan Power Consumption (W):     424.13
(OUTDOOR UNIT)
             Inlet Temperature (°F):    82.21
              Exit Temperature (°F):    96.90
    Condensing Unit Temp Gain (°F):     14.69
        Fan Power Consumption (W):     159.22
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):     3974.5
        Sensible Capacity (Btu/h):    21311.4
         Overall Capacity (Btu/h):    25285.9
          Sensible Heat Ratio (-):      0.843
    Overall Power Consumption (W):     2311.5
        NET Cooling EER (Btu/h.W):      10.94
   Evaporator Energy Imbalance (%):      4.15
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    46.49
              Exit Temperature (°F):    55.99
              Inlet Pressure (psia):   148.48
               Exit Pressure (psia):   139.73
               Pressure Drop (psid):     8.75
                Exit Superheat (°F):    13.00
        Exit Sat. Temperature (°F):     42.99
       Evaporator Capacity (Btu/h):   26822.0
(CONDENSER)
             Inlet Temperature (°F):   147.53
              Exit Temperature (°F):    90.36
              Inlet Pressure (psia):   333.33
               Exit Pressure (psia):   331.19
               Pressure Drop (psid):     2.14
               Exit Subcooling (°F):     7.83
       Inlet Sat. Temperature (°F):    100.50
        Condenser Capacity (Btu/h):   33714.4
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    90.72
         Cond Unit Exit Pres (psia):   325.49
     Liq-line Pressure Drop (psid):     10.00
       TXV Upstream Pressure (psia):   315.49
           TXV Pressure Drop (psid):   167.01
              Temperature Drop (°F):     1.04
(COMPRESSOR)
          Suction Temperature (°F):     60.98
        Discharge Temperature (°F):    151.99
           Suction Pressure (psia):    137.50
         Discharge Pressure (psia):    334.32
          Discharge Superheat (°F):     51.54
       Comp Bottom Shell Temp (°F):    108.88
             Mass Flow Rate (lbm/h):   368.34
         Comp Power Consumption (W):   1728.2
          Cond Unit Inlet Temp (°F):    58.17
       Cond Unit Inlet Pres (psia):    138.76
```

```
                 HEAT PUMP FAULT TEST SUMMARY

                INDOOR/OUTDOOR CONDITION #: 04
             FAULT TYPE: COMPRESSOR LEAKAGE FAULT
                     FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.04
  Indoor Dry-Bulb Temperature (°F):     69.81
 Indoor Dew-Point Temperature (°F):     50.54
 Outdoor Dry-Bulb Temperature (°F):     82.24
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.81
  Inlet Dew-Point Temperature (°F):     50.54
    Exit Dry-Bulb Temperature (°F):     51.06
   Exit Dew-Point Temperature (°F):     47.71
       Inlet Relative Humidity (-):     0.504
        Exit Relative Humidity (-):     0.883
    Evaporator Coil Temp Drop (°F):     18.75
              Air Flow Rate (SCFM):    1021.6
        Fan Power Consumption (W):     424.86
(OUTDOOR UNIT)
             Inlet Temperature (°F):    82.24
              Exit Temperature (°F):    96.58
    Condensing Unit Temp Gain (°F):     14.34
        Fan Power Consumption (W):     159.18
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):     3834.9
        Sensible Capacity (Btu/h):    20970.3
         Overall Capacity (Btu/h):    24805.2
          Sensible Heat Ratio (-):      0.845
    Overall Power Consumption (W):     2301.4
        NET Cooling EER (Btu/h.W):      10.78
   Evaporator Energy Imbalance (%):      3.40
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    46.59
              Exit Temperature (°F):    56.01
              Inlet Pressure (psia):   148.64
               Exit Pressure (psia):   140.43
               Pressure Drop (psid):     8.20
                Exit Superheat (°F):    12.72
        Exit Sat. Temperature (°F):     43.29
       Evaporator Capacity (Btu/h):   26118.1
(CONDENSER)
             Inlet Temperature (°F):   147.48
              Exit Temperature (°F):    90.04
              Inlet Pressure (psia):   331.59
               Exit Pressure (psia):   329.52
               Pressure Drop (psid):     2.08
               Exit Subcooling (°F):     7.73
       Inlet Sat. Temperature (°F):    100.12
        Condenser Capacity (Btu/h):   32933.3
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    90.51
         Cond Unit Exit Pres (psia):   324.08
     Liq-line Pressure Drop (psid):      9.43
       TXV Upstream Pressure (psia):   314.65
           TXV Pressure Drop (psid):   166.01
              Temperature Drop (°F):     0.96
(COMPRESSOR)
          Suction Temperature (°F):     61.18
        Discharge Temperature (°F):    152.09
           Suction Pressure (psia):    138.29
         Discharge Pressure (psia):    332.50
          Discharge Superheat (°F):     52.04
       Comp Bottom Shell Temp (°F):    109.16
             Mass Flow Rate (lbm/h):   359.03
         Comp Power Consumption (W):   1717.3
          Cond Unit Inlet Temp (°F):    58.22
       Cond Unit Inlet Pres (psia):    139.53
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 04
       FAULT TYPE: COMPRESSOR LEAKAGE FAULT
               FAULT LEVEL [%]: 9.3
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.01
  Indoor Dry-Bulb Temperature (°F):     69.73
 Indoor Dew-Point Temperature (°F):     50.51
 Outdoor Dry-Bulb Temperature (°F):     81.96
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.73
  Inlet Dew-Point Temperature (°F):     50.51
    Exit Dry-Bulb Temperature (°F):     51.37
   Exit Dew-Point Temperature (°F):     48.04
       Inlet Relative Humidity (-):     0.504
        Exit Relative Humidity (-):     0.883
    Evaporator Coil Temp Drop (°F):     18.36
              Air Flow Rate (SCFM):    1019.1
          Fan Power Consumption (W):   423.19
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.96
               Exit Temperature (°F):   95.77
    Condensing Unit Temp Gain (°F):     13.81
          Fan Power Consumption (W):   159.09
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3363.0
         Sensible Capacity (Btu/h):   20481.5
          Overall Capacity (Btu/h):   23844.5
           Sensible Heat Ratio (-):     0.859
      Overall Power Consumption (W):   2270.0
        NET Cooling EER (Btu/h.W):      10.50
    Evaporator Energy Imbalance (%):     2.73
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     47.01
             Exit Temperature (°F):     56.47
             Inlet Pressure (psia):    149.30
              Exit Pressure (psia):    142.02
              Pressure Drop (psid):      7.29
               Exit Superheat (°F):     12.52
       Exit Sat. Temperature (°F):      43.96
       Evaporator Capacity (Btu/h):   24947.5
(CONDENSER)
            Inlet Temperature (°F):    147.23
             Exit Temperature (°F):     89.63
             Inlet Pressure (psia):    327.05
              Exit Pressure (psia):    325.04
              Pressure Drop (psid):      2.01
              Exit Subcooling (°F):      7.41
      Inlet Sat. Temperature (°F):      99.12
       Condenser Capacity (Btu/h):    31591.7
(LIQUID LINE AND TXV)
         Cond Unit Exit Temp (°F):      89.92
       Cond Unit Exit Pres (psia):     320.09
    Liq-line Pressure Drop (psid):       8.52
     TXV Upstream Pressure (psia):     311.57
         TXV Pressure Drop (psid):     162.27
             Temperature Drop (°F):      0.94
(COMPRESSOR)
          Suction Temperature (°F):     61.71
        Discharge Temperature (°F):    152.12
           Suction Pressure (psia):    139.96
         Discharge Pressure (psia):    328.00
          Discharge Superheat (°F):     53.07
        Comp Bottom Shell Temp (°F):   109.42
           Mass Flow Rate (lbm/h):     342.64
      Comp Power Consumption (W):      1687.8
        Cond Unit Inlet Temp (°F):      58.59
      Cond Unit Inlet Pres (psia):     141.15
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 04
       FAULT TYPE: COMPRESSOR LEAKAGE FAULT
               FAULT LEVEL [%]: 11.4
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.01
  Indoor Dry-Bulb Temperature (°F):     69.68
 Indoor Dew-Point Temperature (°F):     50.55
 Outdoor Dry-Bulb Temperature (°F):     81.96
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.68
  Inlet Dew-Point Temperature (°F):     50.55
    Exit Dry-Bulb Temperature (°F):     51.61
   Exit Dew-Point Temperature (°F):     48.28
       Inlet Relative Humidity (-):     0.506
        Exit Relative Humidity (-):     0.884
    Evaporator Coil Temp Drop (°F):     18.08
              Air Flow Rate (SCFM):    1017.0
          Fan Power Consumption (W):   424.75
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.96
               Exit Temperature (°F):   95.47
    Condensing Unit Temp Gain (°F):     13.51
          Fan Power Consumption (W):   159.66
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3100.6
         Sensible Capacity (Btu/h):   20131.2
          Overall Capacity (Btu/h):   23231.8
           Sensible Heat Ratio (-):     0.867
      Overall Power Consumption (W):   2264.7
        NET Cooling EER (Btu/h.W):      10.26
    Evaporator Energy Imbalance (%):     2.86
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     47.23
             Exit Temperature (°F):     56.76
             Inlet Pressure (psia):    149.71
              Exit Pressure (psia):    142.86
              Pressure Drop (psid):      6.85
               Exit Superheat (°F):     12.45
       Exit Sat. Temperature (°F):      44.31
       Evaporator Capacity (Btu/h):   24354.0
(CONDENSER)
            Inlet Temperature (°F):    147.46
             Exit Temperature (°F):     89.49
             Inlet Pressure (psia):    325.44
              Exit Pressure (psia):    323.50
              Pressure Drop (psid):      1.95
              Exit Subcooling (°F):      7.20
      Inlet Sat. Temperature (°F):      98.76
       Condenser Capacity (Btu/h):    30946.4
(LIQUID LINE AND TXV)
         Cond Unit Exit Temp (°F):      89.83
       Cond Unit Exit Pres (psia):     318.77
    Liq-line Pressure Drop (psid):       8.11
     TXV Upstream Pressure (psia):     310.66
         TXV Pressure Drop (psid):     160.96
             Temperature Drop (°F):      1.01
(COMPRESSOR)
          Suction Temperature (°F):     62.04
        Discharge Temperature (°F):    152.53
           Suction Pressure (psia):    140.88
         Discharge Pressure (psia):    326.40
          Discharge Superheat (°F):     53.83
        Comp Bottom Shell Temp (°F):   109.99
           Mass Flow Rate (lbm/h):     334.82
      Comp Power Consumption (W):      1680.3
        Cond Unit Inlet Temp (°F):      58.95
      Cond Unit Inlet Pres (psia):     142.03
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: COMPRESSOR LEAKAGE FAULT
               FAULT LEVEL [%]: 4.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.51
   Indoor Dry-Bulb Temperature (°F):    80.25
  Indoor Dew-Point Temperature (°F):    60.23
  Outdoor Dry-Bulb Temperature (°F):    81.87
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    80.25
   Inlet Dew-Point Temperature (°F):    60.23
     Exit Dry-Bulb Temperature (°F):    59.64
    Exit Dew-Point Temperature (°F):    56.61
        Inlet Relative Humidity (-):    0.505
         Exit Relative Humidity (-):    0.897
     Evaporator Coil Temp Drop (°F):    20.62
               Air Flow Rate (SCFM):   1014.1
          Fan Power Consumption (W):   417.80
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.87
               Exit Temperature (°F):   98.57
     Condensing Unit Temp Gain (°F):    16.70
          Fan Power Consumption (W):   160.27
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   6523.4
          Sensible Capacity (Btu/h):  23010.5
           Overall Capacity (Btu/h):  29533.9
            Sensible Heat Ratio (-):    0.779
      Overall Power Consumption (W):   2317.8
          NET Cooling EER (Btu/h.W):    12.74
    Evaporator Energy Imbalance (%):     3.22
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   55.33
               Exit Temperature (°F):   66.33
               Inlet Pressure (psia):  170.03
                Exit Pressure (psia):  161.25
                Pressure Drop (psid):    8.77
                 Exit Superheat (°F):   14.68
          Exit Sat. Temperature (°F):   51.65
        Evaporator Capacity (Btu/h):  30947.0
(CONDENSER)
              Inlet Temperature (°F):  146.73
               Exit Temperature (°F):   90.53
               Inlet Pressure (psia):  342.11
                Exit Pressure (psia):  339.60
                Pressure Drop (psid):    2.51
                Exit Subcooling (°F):    8.41
         Inlet Sat. Temperature (°F):  102.41
         Condenser Capacity (Btu/h):  37731.5
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):   91.73
          Cond Unit Exit Pres (psia):  332.65
      Liq-line Pressure Drop (psid):    13.09
        TXV Upstream Pressure (psia):  319.56
           TXV Pressure Drop (psid):   149.53
               Temperature Drop (°F):    0.71
(COMPRESSOR)
            Suction Temperature (°F):   69.50
         Discharge Temperature (°F):   150.51
             Suction Pressure (psia):  158.95
           Discharge Pressure (psia):  343.21
            Discharge Superheat (°F):   48.13
          Comp Bottom Shell Temp (°F):  110.12
              Mass Flow Rate (lbm/h):  418.09
         Comp Power Consumption (W):   1739.7
           Cond Unit Inlet Temp (°F):   67.78
         Cond Unit Inlet Pres (psia):  160.12
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: COMPRESSOR LEAKAGE FAULT
               FAULT LEVEL [%]: 6.7
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.56
   Indoor Dry-Bulb Temperature (°F):    80.23
  Indoor Dew-Point Temperature (°F):    60.32
  Outdoor Dry-Bulb Temperature (°F):    81.90
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    80.23
   Inlet Dew-Point Temperature (°F):    60.32
     Exit Dry-Bulb Temperature (°F):    59.92
    Exit Dew-Point Temperature (°F):    56.90
        Inlet Relative Humidity (-):    0.507
         Exit Relative Humidity (-):    0.897
     Evaporator Coil Temp Drop (°F):    20.31
               Air Flow Rate (SCFM):   1014.9
          Fan Power Consumption (W):   417.63
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.90
               Exit Temperature (°F):   98.18
     Condensing Unit Temp Gain (°F):    16.28
          Fan Power Consumption (W):   160.59
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   6196.6
          Sensible Capacity (Btu/h):  22681.1
           Overall Capacity (Btu/h):  28877.7
            Sensible Heat Ratio (-):    0.785
      Overall Power Consumption (W):   2305.7
          NET Cooling EER (Btu/h.W):    12.53
    Evaporator Energy Imbalance (%):     2.57
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   55.69
               Exit Temperature (°F):   66.60
               Inlet Pressure (psia):  170.84
                Exit Pressure (psia):  162.70
                Pressure Drop (psid):    8.14
                 Exit Superheat (°F):   14.40
          Exit Sat. Temperature (°F):   52.20
        Evaporator Capacity (Btu/h):  30066.9
(CONDENSER)
              Inlet Temperature (°F):  146.52
               Exit Temperature (°F):   90.41
               Inlet Pressure (psia):  339.60
                Exit Pressure (psia):  337.19
                Pressure Drop (psid):    2.41
                Exit Subcooling (°F):    8.20
         Inlet Sat. Temperature (°F):  101.87
         Condenser Capacity (Btu/h):  36764.9
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):   91.49
          Cond Unit Exit Pres (psia):  330.61
      Liq-line Pressure Drop (psid):    12.30
        TXV Upstream Pressure (psia):  318.32
           TXV Pressure Drop (psid):   147.47
               Temperature Drop (°F):    0.66
(COMPRESSOR)
            Suction Temperature (°F):   69.81
         Discharge Temperature (°F):   150.49
             Suction Pressure (psia):  160.46
           Discharge Pressure (psia):  340.72
            Discharge Superheat (°F):   48.65
          Comp Bottom Shell Temp (°F):  110.53
              Mass Flow Rate (lbm/h):  406.38
         Comp Power Consumption (W):   1727.5
           Cond Unit Inlet Temp (°F):   67.99
         Cond Unit Inlet Pres (psia):  161.61
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: COMPRESSOR LEAKAGE FAULT
               FAULT LEVEL [%]: 9.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.57
   Indoor Dry-Bulb Temperature (°F):     80.31
  Indoor Dew-Point Temperature (°F):     60.29
  Outdoor Dry-Bulb Temperature (°F):     81.63
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):     80.31
   Inlet Dew-Point Temperature (°F):     60.29
     Exit Dry-Bulb Temperature (°F):     60.39
    Exit Dew-Point Temperature (°F):     57.25
        Inlet Relative Humidity (-):     0.505
         Exit Relative Humidity (-):     0.893
     Evaporator Coil Temp Drop (°F):     19.92
               Air Flow Rate (SCFM):    1014.4
          Fan Power Consumption (W):    415.14
(OUTDOOR UNIT)
              Inlet Temperature (°F):     81.63
               Exit Temperature (°F):     97.42
     Condensing Unit Temp Gain (°F):     15.79
          Fan Power Consumption (W):    160.61
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):    5537.7
          Sensible Capacity (Btu/h):   22237.8
           Overall Capacity (Btu/h):   27775.5
            Sensible Heat Ratio (-):     0.801
      Overall Power Consumption (W):    2278.7
          NET Cooling EER (Btu/h.W):     12.19
    Evaporator Energy Imbalance (%):      3.48
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):     56.30
               Exit Temperature (°F):     66.93
               Inlet Pressure (psia):    171.40
                Exit Pressure (psia):    163.90
                Pressure Drop (psid):      7.50
                 Exit Superheat (°F):     14.27
         Exit Sat. Temperature (°F):     52.66
        Evaporator Capacity (Btu/h):   29207.2
(CONDENSER)
              Inlet Temperature (°F):    146.14
               Exit Temperature (°F):     90.28
               Inlet Pressure (psia):    335.44
                Exit Pressure (psia):    333.09
                Pressure Drop (psid):      2.35
                Exit Subcooling (°F):      7.77
        Inlet Sat. Temperature (°F):    100.97
         Condenser Capacity (Btu/h):   35796.2
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):     91.11
          Cond Unit Exit Pres (psia):    326.94
      Liq-line Pressure Drop (psid):     11.46
       TXV Upstream Pressure (psia):    315.49
            TXV Pressure Drop (psid):    144.09
               Temperature Drop (°F):      0.94
(COMPRESSOR)
            Suction Temperature (°F):     70.23
          Discharge Temperature (°F):    150.25
              Suction Pressure (psia):    161.76
            Discharge Pressure (psia):    336.43
            Discharge Superheat (°F):     49.34
         Comp Bottom Shell Temp (°F):    111.03
              Mass Flow Rate (lbm/h):    394.41
          Comp Power Consumption (W):    1703.0
           Cond Unit Inlet Temp (°F):     68.59
         Cond Unit Inlet Pres (psia):    162.84
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: COMPRESSOR LEAKAGE FAULT
               FAULT LEVEL [%]: 27.2
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.52
   Indoor Dry-Bulb Temperature (°F):     79.63
  Indoor Dew-Point Temperature (°F):     60.68
  Outdoor Dry-Bulb Temperature (°F):     81.98
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):     79.63
   Inlet Dew-Point Temperature (°F):     60.68
     Exit Dry-Bulb Temperature (°F):     62.24
    Exit Dew-Point Temperature (°F):     58.94
        Inlet Relative Humidity (-):     0.524
         Exit Relative Humidity (-):     0.890
     Evaporator Coil Temp Drop (°F):     17.39
               Air Flow Rate (SCFM):    1009.6
          Fan Power Consumption (W):    418.90
(OUTDOOR UNIT)
              Inlet Temperature (°F):     81.98
               Exit Temperature (°F):     95.05
     Condensing Unit Temp Gain (°F):     13.07
          Fan Power Consumption (W):    161.79
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):    3257.0
          Sensible Capacity (Btu/h):   19341.7
           Overall Capacity (Btu/h):   22598.7
            Sensible Heat Ratio (-):     0.856
      Overall Power Consumption (W):    2211.3
          NET Cooling EER (Btu/h.W):     10.22
    Evaporator Energy Imbalance (%):      1.92
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):     57.25
               Exit Temperature (°F):     69.39
               Inlet Pressure (psia):    175.27
                Exit Pressure (psia):    170.87
                Pressure Drop (psid):      4.40
                 Exit Superheat (°F):     14.15
         Exit Sat. Temperature (°F):     55.25
        Evaporator Capacity (Btu/h):   23467.4
(CONDENSER)
              Inlet Temperature (°F):    149.17
               Exit Temperature (°F):     89.07
               Inlet Pressure (psia):    322.20
                Exit Pressure (psia):    320.37
                Pressure Drop (psid):      1.83
                Exit Subcooling (°F):      7.09
        Inlet Sat. Temperature (°F):     98.03
         Condenser Capacity (Btu/h):   29623.7
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):     89.42
          Cond Unit Exit Pres (psia):    316.46
      Liq-line Pressure Drop (psid):      7.17
       TXV Upstream Pressure (psia):    309.30
            TXV Pressure Drop (psid):    134.03
               Temperature Drop (°F):      0.68
(COMPRESSOR)
            Suction Temperature (°F):     73.16
          Discharge Temperature (°F):    154.77
              Suction Pressure (psia):    169.29
            Discharge Pressure (psia):    322.49
            Discharge Superheat (°F):     56.95
         Comp Bottom Shell Temp (°F):    119.89
              Mass Flow Rate (lbm/h):    317.20
          Comp Power Consumption (W):    1630.6
           Cond Unit Inlet Temp (°F):     70.85
         Cond Unit Inlet Pres (psia):    170.12
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 05
    FAULT TYPE: COMPRESSOR LEAKAGE FAULT
           FAULT LEVEL [%]: 38.2
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.50
  Indoor Dry-Bulb Temperature (°F):     79.64
 Indoor Dew-Point Temperature (°F):     60.71
 Outdoor Dry-Bulb Temperature (°F):     81.91
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.64
  Inlet Dew-Point Temperature (°F):     60.71
    Exit Dry-Bulb Temperature (°F):     63.33
   Exit Dew-Point Temperature (°F):     59.95
       Inlet Relative Humidity (-):     0.524
        Exit Relative Humidity (-):     0.887
    Evaporator Coil Temp Drop (°F):     16.31
              Air Flow Rate (SCFM):    1009.5
        Fan Power Consumption (W):     415.92
(OUTDOOR UNIT)
             Inlet Temperature (°F):    81.91
              Exit Temperature (°F):    93.29
     Condensing Unit Temp Gain (°F):    11.38
         Fan Power Consumption (W):    161.36
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    1440.9
         Sensible Capacity (Btu/h):   18141.8
          Overall Capacity (Btu/h):   19582.7
            Sensible Heat Ratio (-):    0.926
     Overall Power Consumption (W):    2158.8
          NET Cooling EER (Btu/h.W):     9.07
    Evaporator Energy Imbalance (%):    -0.91
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    58.73
              Exit Temperature (°F):    70.94
              Inlet Pressure (psia):   178.26
               Exit Pressure (psia):   175.34
               Pressure Drop (psid):     2.92
                Exit Superheat (°F):    14.08
          Exit Sat. Temperature (°F):    56.86
       Evaporator Capacity (Btu/h):   19818.2
(CONDENSER)
             Inlet Temperature (°F):   151.28
              Exit Temperature (°F):    88.62
              Inlet Pressure (psia):   312.47
               Exit Pressure (psia):   310.88
               Pressure Drop (psid):     1.60
               Exit Subcooling (°F):     5.93
         Inlet Sat. Temperature (°F):    95.81
        Condenser Capacity (Btu/h):   25618.4
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    88.66
          Cond Unit Exit Pres (psia):   308.12
      Liq-line Pressure Drop (psid):     5.07
        TXV Upstream Pressure (psia):   303.05
           TXV Pressure Drop (psid):   124.79
              Temperature Drop (°F):     0.72
(COMPRESSOR)
           Suction Temperature (°F):    75.10
         Discharge Temperature (°F):   158.40
            Suction Pressure (psia):   173.94
          Discharge Pressure (psia):   312.13
           Discharge Superheat (°F):    62.95
         Comp Bottom Shell Temp (°F):   126.79
            Mass Flow Rate (lbm/h):   269.23
        Comp Power Consumption (W):    1581.6
           Cond Unit Inlet Temp (°F):    72.39
         Cond Unit Inlet Pres (psia):   174.71
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 08
    FAULT TYPE: COMPRESSOR LEAKAGE FAULT
           FAULT LEVEL [%]: 2.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.06
  Indoor Dry-Bulb Temperature (°F):     70.06
 Indoor Dew-Point Temperature (°F):     50.64
 Outdoor Dry-Bulb Temperature (°F):    100.11
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.06
  Inlet Dew-Point Temperature (°F):     50.64
    Exit Dry-Bulb Temperature (°F):     52.44
   Exit Dew-Point Temperature (°F):     48.81
       Inlet Relative Humidity (-):     0.501
        Exit Relative Humidity (-):     0.874
    Evaporator Coil Temp Drop (°F):     17.62
              Air Flow Rate (SCFM):    1019.5
        Fan Power Consumption (W):     420.29
(OUTDOOR UNIT)
             Inlet Temperature (°F):   100.11
              Exit Temperature (°F):   114.70
     Condensing Unit Temp Gain (°F):    14.59
         Fan Power Consumption (W):    155.39
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2518.0
         Sensible Capacity (Btu/h):   19669.1
          Overall Capacity (Btu/h):   22187.2
            Sensible Heat Ratio (-):    0.887
     Overall Power Consumption (W):    2774.9
          NET Cooling EER (Btu/h.W):     8.00
    Evaporator Energy Imbalance (%):     4.36
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    48.76
              Exit Temperature (°F):    56.91
              Inlet Pressure (psia):   153.67
               Exit Pressure (psia):   143.74
               Pressure Drop (psid):     9.93
                Exit Superheat (°F):    12.23
          Exit Sat. Temperature (°F):    44.68
       Evaporator Capacity (Btu/h):   23638.9
(CONDENSER)
             Inlet Temperature (°F):   176.36
              Exit Temperature (°F):   109.66
              Inlet Pressure (psia):   419.23
               Exit Pressure (psia):   417.37
               Pressure Drop (psid):     1.86
               Exit Subcooling (°F):     6.65
         Inlet Sat. Temperature (°F):   117.72
        Condenser Capacity (Btu/h):   32289.6
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   109.54
          Cond Unit Exit Pres (psia):   411.99
      Liq-line Pressure Drop (psid):    10.62
        TXV Upstream Pressure (psia):   401.37
           TXV Pressure Drop (psid):   247.70
              Temperature Drop (°F):     1.42
(COMPRESSOR)
           Suction Temperature (°F):    63.97
         Discharge Temperature (°F):   181.86
            Suction Pressure (psia):   141.66
          Discharge Pressure (psia):   420.41
           Discharge Superheat (°F):    64.15
         Comp Bottom Shell Temp (°F):   126.60
            Mass Flow Rate (lbm/h):   365.90
        Comp Power Consumption (W):    2199.2
           Cond Unit Inlet Temp (°F):    59.64
         Cond Unit Inlet Pres (psia):   142.84
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 08
          FAULT TYPE: COMPRESSOR LEAKAGE FAULT
                  FAULT LEVEL [%]: 5.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.04
  Indoor Dry-Bulb Temperature (°F):     70.00
 Indoor Dew-Point Temperature (°F):     50.71
 Outdoor Dry-Bulb Temperature (°F):    100.09
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.00
  Inlet Dew-Point Temperature (°F):     50.71
    Exit Dry-Bulb Temperature (°F):     52.69
   Exit Dew-Point Temperature (°F):     49.03
       Inlet Relative Humidity (-):     0.503
        Exit Relative Humidity (-):     0.873
    Evaporator Coil Temp Drop (°F):     17.31
             Air Flow Rate (SCFM):     1016.1
         Fan Power Consumption (W):    419.31
(OUTDOOR UNIT)
                Inlet Temperature (°F):    100.09
                 Exit Temperature (°F):    114.30
    Condensing Unit Temp Gain (°F):     14.21
         Fan Power Consumption (W):    155.37
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2312.2
         Sensible Capacity (Btu/h):   19256.9
          Overall Capacity (Btu/h):   21569.1
           Sensible Heat Ratio (-):     0.893
     Overall Power Consumption (W):    2754.8
         NET Cooling EER (Btu/h.W):      7.83
   Evaporator Energy Imbalance (%):      4.03
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     48.96
             Exit Temperature (°F):     57.20
             Inlet Pressure (psia):    153.95
              Exit Pressure (psia):    144.79
              Pressure Drop (psid):      9.16
               Exit Superheat (°F):     12.09
        Exit Sat. Temperature (°F):     45.12
       Evaporator Capacity (Btu/h):   22912.2
(CONDENSER)
            Inlet Temperature (°F):    176.61
             Exit Temperature (°F):    109.44
             Inlet Pressure (psia):    416.38
              Exit Pressure (psia):    414.57
              Pressure Drop (psid):      1.81
              Exit Subcooling (°F):      6.46
       Inlet Sat. Temperature (°F):    117.20
        Condenser Capacity (Btu/h):   31433.4
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    109.25
        Cond Unit Exit Pres (psia):    409.47
     Liq-line Pressure Drop (psid):      9.82
      TXV Upstream Pressure (psia):    399.65
          TXV Pressure Drop (psid):    245.70
             Temperature Drop (°F):      1.44
(COMPRESSOR)
          Suction Temperature (°F):     64.40
        Discharge Temperature (°F):    182.35
           Suction Pressure (psia):    142.78
         Discharge Pressure (psia):    417.52
          Discharge Superheat (°F):     65.17
       Comp Bottom Shell Temp (°F):    126.88
            Mass Flow Rate (lbm/h):    354.63
      Comp Power Consumption (W):    2180.1
         Cond Unit Inlet Temp (°F):     59.97
       Cond Unit Inlet Pres (psia):    143.93
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 08
          FAULT TYPE: COMPRESSOR LEAKAGE FAULT
                  FAULT LEVEL [%]: 9.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.00
  Indoor Dry-Bulb Temperature (°F):     70.01
 Indoor Dew-Point Temperature (°F):     50.70
 Outdoor Dry-Bulb Temperature (°F):    100.05
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.01
  Inlet Dew-Point Temperature (°F):     50.70
    Exit Dry-Bulb Temperature (°F):     53.01
   Exit Dew-Point Temperature (°F):     49.33
       Inlet Relative Humidity (-):     0.503
        Exit Relative Humidity (-):     0.873
    Evaporator Coil Temp Drop (°F):     17.00
             Air Flow Rate (SCFM):     1012.5
         Fan Power Consumption (W):    418.53
(OUTDOOR UNIT)
            Inlet Temperature (°F):    100.05
             Exit Temperature (°F):    113.89
    Condensing Unit Temp Gain (°F):     13.84
         Fan Power Consumption (W):    155.18
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    1890.4
         Sensible Capacity (Btu/h):   18854.3
          Overall Capacity (Btu/h):   20744.7
           Sensible Heat Ratio (-):     0.909
     Overall Power Consumption (W):    2736.8
         NET Cooling EER (Btu/h.W):      7.58
   Evaporator Energy Imbalance (%):      4.08
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     49.15
             Exit Temperature (°F):     57.56
             Inlet Pressure (psia):    154.36
              Exit Pressure (psia):    145.89
              Pressure Drop (psid):      8.47
               Exit Superheat (°F):     11.99
        Exit Sat. Temperature (°F):     45.57
       Evaporator Capacity (Btu/h):   22062.8
(CONDENSER)
            Inlet Temperature (°F):    177.26
             Exit Temperature (°F):    109.20
             Inlet Pressure (psia):    413.38
              Exit Pressure (psia):    411.64
              Pressure Drop (psid):      1.74
              Exit Subcooling (°F):      6.28
       Inlet Sat. Temperature (°F):    116.64
        Condenser Capacity (Btu/h):   30453.1
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    108.96
        Cond Unit Exit Pres (psia):    406.94
     Liq-line Pressure Drop (psid):      9.08
      TXV Upstream Pressure (psia):    397.85
          TXV Pressure Drop (psid):    243.49
             Temperature Drop (°F):      1.45
(COMPRESSOR)
          Suction Temperature (°F):     64.95
        Discharge Temperature (°F):    183.27
           Suction Pressure (psia):    143.98
         Discharge Pressure (psia):    414.54
          Discharge Superheat (°F):     66.64
       Comp Bottom Shell Temp (°F):    127.28
            Mass Flow Rate (lbm/h):    341.54
        Comp Power Consumption (W):    2163.1
         Cond Unit Inlet Temp (°F):     60.37
       Cond Unit Inlet Pres (psia):    145.09
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 09
     FAULT TYPE: COMPRESSOR LEAKAGE FAULT
             FAULT LEVEL [%]: 2.4
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.40
  Indoor Dry-Bulb Temperature (°F):     80.28
 Indoor Dew-Point Temperature (°F):     60.42
 Outdoor Dry-Bulb Temperature (°F):     99.69
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.28
  Inlet Dew-Point Temperature (°F):     60.42
    Exit Dry-Bulb Temperature (°F):     60.83
   Exit Dew-Point Temperature (°F):     57.55
       Inlet Relative Humidity (-):     0.508
        Exit Relative Humidity (-):     0.889
    Evaporator Coil Temp Drop (°F):     19.45
              Air Flow Rate (SCFM):    1008.0
          Fan Power Consumption (W):    415.56
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.69
              Exit Temperature (°F):    116.28
    Condensing Unit Temp Gain (°F):     16.59
          Fan Power Consumption (W):    156.61
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    5257.4
         Sensible Capacity (Btu/h):   21582.8
          Overall Capacity (Btu/h):   26840.2
           Sensible Heat Ratio (-):     0.804
      Overall Power Consumption (W):   2789.3
         NET Cooling EER (Btu/h.W):      9.62
   Evaporator Energy Imbalance (%):      2.51
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     56.74
              Exit Temperature (°F):     67.23
              Inlet Pressure (psia):    175.17
               Exit Pressure (psia):    164.32
               Pressure Drop (psid):     10.86
                Exit Superheat (°F):     14.42
        Exit Sat. Temperature (°F):     52.81
       Evaporator Capacity (Btu/h):   27958.2
(CONDENSER)
             Inlet Temperature (°F):    174.44
              Exit Temperature (°F):    109.21
              Inlet Pressure (psia):    429.77
               Exit Pressure (psia):    427.61
               Pressure Drop (psid):      2.16
               Exit Subcooling (°F):      7.96
       Inlet Sat. Temperature (°F):    119.64
        Condenser Capacity (Btu/h):   36622.6
(LIQUID LINE AND TXV)
         Cond Unit Exit Temp (°F):     109.72
        Cond Unit Exit Pres (psia):    420.07
      Liq-line Pressure Drop (psid):     14.34
      TXV Upstream Pressure (psia):    405.74
          TXV Pressure Drop (psid):    230.57
             Temperature Drop (°F):      0.94
(COMPRESSOR)
           Suction Temperature (°F):     72.10
         Discharge Temperature (°F):    178.88
            Suction Pressure (psia):    162.13
          Discharge Pressure (psia):    430.57
           Discharge Superheat (°F):     59.32
        Comp Bottom Shell Temp (°F):    125.73
             Mass Flow Rate (lbm/h):    421.72
         Comp Power Consumption (W):    2217.1
          Cond Unit Inlet Temp (°F):     69.18
       Cond Unit Inlet Pres (psia):    163.25
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 09
     FAULT TYPE: COMPRESSOR LEAKAGE FAULT
             FAULT LEVEL [%]: 5.6
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.97
  Indoor Dry-Bulb Temperature (°F):     80.12
 Indoor Dew-Point Temperature (°F):     60.58
 Outdoor Dry-Bulb Temperature (°F):    100.08
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.12
  Inlet Dew-Point Temperature (°F):     60.58
    Exit Dry-Bulb Temperature (°F):     61.48
   Exit Dew-Point Temperature (°F):     57.98
       Inlet Relative Humidity (-):     0.514
        Exit Relative Humidity (-):     0.883
    Evaporator Coil Temp Drop (°F):     18.64
              Air Flow Rate (SCFM):    1028.4
          Fan Power Consumption (W):    421.13
(OUTDOOR UNIT)
             Inlet Temperature (°F):    100.08
              Exit Temperature (°F):    115.98
    Condensing Unit Temp Gain (°F):     15.90
          Fan Power Consumption (W):    158.06
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4811.8
         Sensible Capacity (Btu/h):   21101.8
          Overall Capacity (Btu/h):   25913.6
           Sensible Heat Ratio (-):     0.814
      Overall Power Consumption (W):   2784.8
         NET Cooling EER (Btu/h.W):      9.31
   Evaporator Energy Imbalance (%):      2.41
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     56.25
              Exit Temperature (°F):     67.12
              Inlet Pressure (psia):    174.75
               Exit Pressure (psia):    164.83
               Pressure Drop (psid):      9.92
                Exit Superheat (°F):     14.11
        Exit Sat. Temperature (°F):     53.01
       Evaporator Capacity (Btu/h):   26983.9
(CONDENSER)
             Inlet Temperature (°F):    174.95
              Exit Temperature (°F):    109.12
              Inlet Pressure (psia):    427.98
               Exit Pressure (psia):    425.89
               Pressure Drop (psid):      2.09
               Exit Subcooling (°F):      8.00
       Inlet Sat. Temperature (°F):    119.32
        Condenser Capacity (Btu/h):   35586.3
(LIQUID LINE AND TXV)
         Cond Unit Exit Temp (°F):     109.47
        Cond Unit Exit Pres (psia):    418.89
      Liq-line Pressure Drop (psid):     13.28
      TXV Upstream Pressure (psia):    405.61
          TXV Pressure Drop (psid):    230.86
             Temperature Drop (°F):      1.02
(COMPRESSOR)
           Suction Temperature (°F):     72.36
         Discharge Temperature (°F):    179.68
            Suction Pressure (psia):    162.80
          Discharge Pressure (psia):    428.84
           Discharge Superheat (°F):     60.43
        Comp Bottom Shell Temp (°F):    126.68
             Mass Flow Rate (lbm/h):    407.75
         Comp Power Consumption (W):    2205.6
          Cond Unit Inlet Temp (°F):     69.21
       Cond Unit Inlet Pres (psia):    163.91
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
      FAULT TYPE: COMPRESSOR LEAKAGE FAULT
              FAULT LEVEL [%]: 8.9
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.36
  Indoor Dry-Bulb Temperature (°F):    80.23
 Indoor Dew-Point Temperature (°F):    60.52
 Outdoor Dry-Bulb Temperature (°F):    99.72
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.23
  Inlet Dew-Point Temperature (°F):    60.52
    Exit Dry-Bulb Temperature (°F):    61.53
   Exit Dew-Point Temperature (°F):    58.18
       Inlet Relative Humidity (-):    0.511
        Exit Relative Humidity (-):    0.887
    Evaporator Coil Temp Drop (°F):    18.70
              Air Flow Rate (SCFM):   1007.7
        Fan Power Consumption (W):    419.75
(OUTDOOR UNIT)
              Inlet Temperature (°F):  99.72
               Exit Temperature (°F): 115.44
    Condensing Unit Temp Gain (°F):    15.72
        Fan Power Consumption (W):    156.92
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4343.6
         Sensible Capacity (Btu/h):  20748.3
          Overall Capacity (Btu/h):  25091.9
           Sensible Heat Ratio (-):    0.827
     Overall Power Consumption (W):   2762.3
        NET Cooling EER (Btu/h.W):      9.08
   Evaporator Energy Imbalance (%):     2.14
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):  57.41
               Exit Temperature (°F):  67.99
               Inlet Pressure (psia): 176.32
                Exit Pressure (psia): 167.08
                Pressure Drop (psid):   9.24
                 Exit Superheat (°F):  14.14
        Exit Sat. Temperature (°F):    53.85
      Evaporator Capacity (Btu/h):   26068.9
(CONDENSER)
              Inlet Temperature (°F): 174.93
               Exit Temperature (°F): 108.83
               Inlet Pressure (psia): 423.54
                Exit Pressure (psia): 421.54
                Pressure Drop (psid):   2.01
                Exit Subcooling (°F):   7.58
       Inlet Sat. Temperature (°F):   118.51
        Condenser Capacity (Btu/h):  34489.3
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   109.17
        Cond Unit Exit Pres (psia):   415.00
      Liq-line Pressure Drop (psid):   12.33
       TXV Upstream Pressure (psia):  402.67
           TXV Pressure Drop (psid):  226.35
              Temperature Drop (°F):    0.97
(COMPRESSOR)
          Suction Temperature (°F):    73.11
        Discharge Temperature (°F):   179.88
             Suction Pressure (psia): 165.12
          Discharge Pressure (psia):  424.27
          Discharge Superheat (°F):    61.46
       Comp Bottom Shell Temp (°F):   126.82
             Mass Flow Rate (lbm/h):  393.46
       Comp Power Consumption (W):   2185.6
          Cond Unit Inlet Temp (°F):   69.99
       Cond Unit Inlet Pres (psia):   166.19
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
      FAULT TYPE: COMPRESSOR LEAKAGE FAULT
              FAULT LEVEL [%]: 11.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.34
  Indoor Dry-Bulb Temperature (°F):    80.18
 Indoor Dew-Point Temperature (°F):    60.72
 Outdoor Dry-Bulb Temperature (°F):    99.78
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.18
  Inlet Dew-Point Temperature (°F):    60.72
    Exit Dry-Bulb Temperature (°F):    61.83
   Exit Dew-Point Temperature (°F):    58.52
       Inlet Relative Humidity (-):    0.515
        Exit Relative Humidity (-):    0.889
    Evaporator Coil Temp Drop (°F):    18.34
              Air Flow Rate (SCFM):   1004.4
        Fan Power Consumption (W):    416.67
(OUTDOOR UNIT)
              Inlet Temperature (°F):  99.78
               Exit Temperature (°F): 115.27
    Condensing Unit Temp Gain (°F):    15.49
        Fan Power Consumption (W):    155.89
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4108.6
         Sensible Capacity (Btu/h):  20294.6
          Overall Capacity (Btu/h):  24403.2
           Sensible Heat Ratio (-):    0.832
     Overall Power Consumption (W):   2742.9
        NET Cooling EER (Btu/h.W):      8.90
   Evaporator Energy Imbalance (%):     1.93
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):  57.74
               Exit Temperature (°F):  68.25
               Inlet Pressure (psia): 177.06
                Exit Pressure (psia): 168.45
                Pressure Drop (psid):   8.61
                 Exit Superheat (°F):  13.90
        Exit Sat. Temperature (°F):    54.35
      Evaporator Capacity (Btu/h):   25309.0
(CONDENSER)
              Inlet Temperature (°F): 175.37
               Exit Temperature (°F): 108.80
               Inlet Pressure (psia): 421.76
                Exit Pressure (psia): 419.81
                Pressure Drop (psid):   1.95
                Exit Subcooling (°F):   7.54
       Inlet Sat. Temperature (°F):   118.19
        Condenser Capacity (Btu/h):  33623.5
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   108.95
        Cond Unit Exit Pres (psia):   413.58
      Liq-line Pressure Drop (psid):   11.61
       TXV Upstream Pressure (psia):  401.97
           TXV Pressure Drop (psid):  224.91
              Temperature Drop (°F):    0.95
(COMPRESSOR)
          Suction Temperature (°F):    73.55
        Discharge Temperature (°F):   180.44
             Suction Pressure (psia): 166.54
          Discharge Pressure (psia):  422.49
          Discharge Superheat (°F):    62.35
       Comp Bottom Shell Temp (°F):   127.50
             Mass Flow Rate (lbm/h):  382.09
       Comp Power Consumption (W):   2170.4
          Cond Unit Inlet Temp (°F):   70.32
       Cond Unit Inlet Pres (psia):   167.55
```

D.3 Improper Outdoor Air Flow Fault Tests

Table D.3. List of raw data for improper outdoor air flow fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	CF	10.0
4	70	50	82	CF	20.0
4	70	50	82	CF	35.0
5	80	50	82	CF	5.0
5	80	50	82	CF	10.0
5	80	50	82	CF	20.0
5	80	50	82	CF	35.0
5	80	50	82	CF	50.0
8	70	50	100	CF	10.0
8	70	50	100	CF	20.0
8	70	50	100	CF	35.0
9	80	50	100	CF	5.0
9	80	50	100	CF	10.0
9	80	50	100	CF	20.0
9	80	50	100	CF	35.0

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 04
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.55
  Indoor Dry-Bulb Temperature (°F):     70.03
 Indoor Dew-Point Temperature (°F):     50.10
 Outdoor Dry-Bulb Temperature (°F):     81.54
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.03
  Inlet Dew-Point Temperature (°F):     50.10
    Exit Dry-Bulb Temperature (°F):     50.62
   Exit Dew-Point Temperature (°F):     47.11
       Inlet Relative Humidity (-):     0.492
        Exit Relative Humidity (-):     0.877
    Evaporator Coil Temp Drop (°F):     19.41
              Air Flow Rate (SCFM):    1038.1
         Fan Power Consumption (W):    425.46
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.54
             Exit Temperature (°F):     96.54
    Condensing Unit Temp Gain (°F):     15.00
         Fan Power Consumption (W):    160.54
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3977.8
         Sensible Capacity (Btu/h):   22044.2
          Overall Capacity (Btu/h):   26021.9
           Sensible Heat Ratio (-):     0.847
     Overall Power Consumption (W):    2315.7
        NET Cooling EER (Btu/h.W):     11.24
   Evaporator Energy Imbalance (%):      3.74
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     46.10
             Exit Temperature (°F):     55.47
             Inlet Pressure (psia):    147.16
              Exit Pressure (psia):    138.00
              Pressure Drop (psid):      9.16
               Exit Superheat (°F):     13.22
       Exit Sat. Temperature (°F):     42.25
      Evaporator Capacity (Btu/h):   27475.1
(CONDENSER)
            Inlet Temperature (°F):    147.53
             Exit Temperature (°F):     88.83
             Inlet Pressure (psia):    333.00
              Exit Pressure (psia):    330.81
              Pressure Drop (psid):      2.19
              Exit Subcooling (°F):      7.61
      Inlet Sat. Temperature (°F):    100.43
       Condenser Capacity (Btu/h):   34507.4
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     90.80
         Cond Unit Exit Pres (psia):   324.87
     Liq-line Pressure Drop (psid):     10.38
      TXV Upstream Pressure (psia):    314.49
          TXV Pressure Drop (psid):    167.33
             Temperature Drop (°F):      0.99
(COMPRESSOR)
          Suction Temperature (°F):     60.26
        Discharge Temperature (°F):    151.99
           Suction Pressure (psia):    135.72
         Discharge Pressure (psia):    333.92
          Discharge Superheat (°F):     51.63
       Comp Bottom Shell Temp (°F):    108.47
           Mass Flow Rate (lbm/h):    377.09
        Comp Power Consumption (W):    1729.7
          Cond Unit Inlet Temp (°F):    57.74
       Cond Unit Inlet Pres (psia):    137.05
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 04
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.67
  Indoor Dry-Bulb Temperature (°F):     69.93
 Indoor Dew-Point Temperature (°F):     50.18
 Outdoor Dry-Bulb Temperature (°F):     81.80
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.93
  Inlet Dew-Point Temperature (°F):     50.18
    Exit Dry-Bulb Temperature (°F):     50.92
   Exit Dew-Point Temperature (°F):     47.46
       Inlet Relative Humidity (-):     0.495
        Exit Relative Humidity (-):     0.879
    Evaporator Coil Temp Drop (°F):     19.00
              Air Flow Rate (SCFM):    1040.8
         Fan Power Consumption (W):    426.70
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.80
             Exit Temperature (°F):     96.70
    Condensing Unit Temp Gain (°F):     14.90
         Fan Power Consumption (W):    161.87
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3635.3
         Sensible Capacity (Btu/h):   21640.5
          Overall Capacity (Btu/h):   25275.8
           Sensible Heat Ratio (-):     0.856
     Overall Power Consumption (W):    2341.5
        NET Cooling EER (Btu/h.W):     10.80
   Evaporator Energy Imbalance (%):      3.17
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     46.96
             Exit Temperature (°F):     56.09
             Inlet Pressure (psia):    149.05
              Exit Pressure (psia):    139.10
              Pressure Drop (psid):      9.96
               Exit Superheat (°F):     13.36
       Exit Sat. Temperature (°F):     42.72
      Evaporator Capacity (Btu/h):   26544.2
(CONDENSER)
            Inlet Temperature (°F):    149.24
             Exit Temperature (°F):     88.18
             Inlet Pressure (psia):    338.26
              Exit Pressure (psia):    336.04
              Pressure Drop (psid):      2.22
              Exit Subcooling (°F):      1.89
      Inlet Sat. Temperature (°F):    101.58
       Condenser Capacity (Btu/h):   33680.8
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     97.36
         Cond Unit Exit Pres (psia):   328.62
     Liq-line Pressure Drop (psid):     10.72
      TXV Upstream Pressure (psia):    317.90
          TXV Pressure Drop (psid):    168.85
             Temperature Drop (°F):      1.33
(COMPRESSOR)
          Suction Temperature (°F):     60.75
        Discharge Temperature (°F):    153.82
           Suction Pressure (psia):    136.87
         Discharge Pressure (psia):    339.27
          Discharge Superheat (°F):     52.30
       Comp Bottom Shell Temp (°F):    108.96
           Mass Flow Rate (lbm/h):    378.71
        Comp Power Consumption (W):    1752.9
          Cond Unit Inlet Temp (°F):    58.16
       Cond Unit Inlet Pres (psia):    138.15
```

```
            HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 35.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.54
  Indoor Dry-Bulb Temperature (°F):    70.03
 Indoor Dew-Point Temperature (°F):    50.12
 Outdoor Dry-Bulb Temperature (°F):    81.65
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.03
  Inlet Dew-Point Temperature (°F):    50.12
    Exit Dry-Bulb Temperature (°F):    51.13
   Exit Dew-Point Temperature (°F):    47.67
       Inlet Relative Humidity (-):    0.492
        Exit Relative Humidity (-):    0.879
    Evaporator Coil Temp Drop (°F):    18.90
              Air Flow Rate (SCFM):   1037.0
         Fan Power Consumption (W):   426.11
(OUTDOOR UNIT)
            Inlet Temperature (°F):    81.65
             Exit Temperature (°F):    96.92
    Condensing Unit Temp Gain (°F):    15.26
         Fan Power Consumption (W):   163.51
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   3288.1
         Sensible Capacity (Btu/h):  21452.6
          Overall Capacity (Btu/h):  24740.6
           Sensible Heat Ratio (-):    0.867
     Overall Power Consumption (W):   2429.5
        NET Cooling EER (Btu/h.W):    10.18
   Evaporator Energy Imbalance (%):     3.92
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    46.87
             Exit Temperature (°F):    58.39
             Inlet Pressure (psia):   149.87
              Exit Pressure (psia):   139.56
              Pressure Drop (psid):    10.31
               Exit Superheat (°F):    15.48
         Exit Sat. Temperature (°F):    42.92
      Evaporator Capacity (Btu/h):  26193.3
(CONDENSER)
            Inlet Temperature (°F):   156.08
             Exit Temperature (°F):    86.72
             Inlet Pressure (psia):   353.75
              Exit Pressure (psia):   351.66
              Pressure Drop (psid):     2.10
              Exit Subcooling (°F):     0.77
       Inlet Sat. Temperature (°F):   104.88
       Condenser Capacity (Btu/h):  33592.7
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   101.67
        Cond Unit Exit Pres (psia):   343.23
     Liq-line Pressure Drop (psid):    12.19
      TXV Upstream Pressure (psia):   331.04
          TXV Pressure Drop (psid):   181.17
             Temperature Drop (°F):     2.41
(COMPRESSOR)
          Suction Temperature (°F):    62.92
        Discharge Temperature (°F):   160.43
           Suction Pressure (psia):   137.32
         Discharge Pressure (psia):   354.58
          Discharge Superheat (°F):    55.63
       Comp Bottom Shell Temp (°F):   112.22
            Mass Flow Rate (lbm/h):   380.75
        Comp Power Consumption (W):   1839.9
         Cond Unit Inlet Temp (°F):    60.47
       Cond Unit Inlet Pres (psia):   138.64
```

```
            HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 05
    FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.40
  Indoor Dry-Bulb Temperature (°F):    80.26
 Indoor Dew-Point Temperature (°F):    60.41
 Outdoor Dry-Bulb Temperature (°F):    81.81
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.26
  Inlet Dew-Point Temperature (°F):    60.41
    Exit Dry-Bulb Temperature (°F):    59.38
   Exit Dew-Point Temperature (°F):    56.25
       Inlet Relative Humidity (-):    0.508
        Exit Relative Humidity (-):    0.894
    Evaporator Coil Temp Drop (°F):    20.88
              Air Flow Rate (SCFM):   1011.5
         Fan Power Consumption (W):   417.37
(OUTDOOR UNIT)
            Inlet Temperature (°F):    81.81
             Exit Temperature (°F):    99.19
    Condensing Unit Temp Gain (°F):    17.38
         Fan Power Consumption (W):   160.21
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   7482.2
         Sensible Capacity (Btu/h):  23237.6
          Overall Capacity (Btu/h):  30719.7
           Sensible Heat Ratio (-):    0.756
     Overall Power Consumption (W):   2344.1
        NET Cooling EER (Btu/h.W):    13.11
   Evaporator Energy Imbalance (%):     3.62
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    54.31
             Exit Temperature (°F):    65.84
             Inlet Pressure (psia):   168.99
              Exit Pressure (psia):   159.22
              Pressure Drop (psid):     9.77
               Exit Superheat (°F):    14.97
         Exit Sat. Temperature (°F):    50.87
      Evaporator Capacity (Btu/h):  32305.8
(CONDENSER)
            Inlet Temperature (°F):   147.77
             Exit Temperature (°F):    90.45
             Inlet Pressure (psia):   346.28
              Exit Pressure (psia):   343.65
              Pressure Drop (psid):     2.63
              Exit Subcooling (°F):     9.17
       Inlet Sat. Temperature (°F):   103.31
       Condenser Capacity (Btu/h):  39337.9
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    91.73
        Cond Unit Exit Pres (psia):   336.12
     Liq-line Pressure Drop (psid):    14.10
      TXV Upstream Pressure (psia):   322.02
          TXV Pressure Drop (psid):   153.04
             Temperature Drop (°F):     0.63
(COMPRESSOR)
          Suction Temperature (°F):    68.97
        Discharge Temperature (°F):   151.50
           Suction Pressure (psia):   156.77
         Discharge Pressure (psia):   347.56
          Discharge Superheat (°F):    48.19
       Comp Bottom Shell Temp (°F):   109.72
            Mass Flow Rate (lbm/h):   435.43
        Comp Power Consumption (W):   1766.5
         Cond Unit Inlet Temp (°F):    67.35
       Cond Unit Inlet Pres (psia):   158.00
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
             FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.39
  Indoor Dry-Bulb Temperature (°F):     79.93
 Indoor Dew-Point Temperature (°F):     60.32
 Outdoor Dry-Bulb Temperature (°F):     81.75
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.93
  Inlet Dew-Point Temperature (°F):     60.32
    Exit Dry-Bulb Temperature (°F):     59.44
   Exit Dew-Point Temperature (°F):     56.24
       Inlet Relative Humidity (-):     0.512
        Exit Relative Humidity (-):     0.891
    Evaporator Coil Temp Drop (°F):     20.50
              Air Flow Rate (SCFM):    1011.9
         Fan Power Consumption (W):    416.29
(OUTDOOR UNIT)
             Inlet Temperature (°F):    81.75
              Exit Temperature (°F):    99.05
    Condensing Unit Temp Gain (°F):     17.30
         Fan Power Consumption (W):    160.54
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    7329.2
         Sensible Capacity (Btu/h):   22824.4
          Overall Capacity (Btu/h):   30153.6
           Sensible Heat Ratio (-):     0.757
     Overall Power Consumption (W):    2348.5
         NET Cooling EER (Btu/h.W):     12.84
   Evaporator Energy Imbalance (%):      4.26
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    54.16
              Exit Temperature (°F):    65.20
              Inlet Pressure (psia):   168.49
               Exit Pressure (psia):   158.50
               Pressure Drop (psid):     9.99
                Exit Superheat (°F):    14.60
         Exit Sat. Temperature (°F):    50.60
       Evaporator Capacity (Btu/h):   31928.9
(CONDENSER)
             Inlet Temperature (°F):   148.06
              Exit Temperature (°F):    89.79
              Inlet Pressure (psia):   347.04
               Exit Pressure (psia):   344.49
               Pressure Drop (psid):     2.55
               Exit Subcooling (°F):     8.54
        Inlet Sat. Temperature (°F):   103.47
        Condenser Capacity (Btu/h):   38983.0
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    92.54
         Cond Unit Exit Pres (psia):   336.94
     Liq-line Pressure Drop (psid):     14.20
      TXV Upstream Pressure (psia):    322.74
          TXV Pressure Drop (psid):    154.25
              Temperature Drop (°F):     0.57
(COMPRESSOR)
           Suction Temperature (°F):    68.44
         Discharge Temperature (°F):   151.65
            Suction Pressure (psia):   156.04
          Discharge Pressure (psia):   348.36
           Discharge Superheat (°F):    48.17
        Comp Bottom Shell Temp (°F):   109.80
             Mass Flow Rate (lbm/h):   433.13
        Comp Power Consumption (W):    1771.7
          Cond Unit Inlet Temp (°F):    66.81
        Cond Unit Inlet Pres (psia):   157.33
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
             FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.40
  Indoor Dry-Bulb Temperature (°F):     80.17
 Indoor Dew-Point Temperature (°F):     60.39
 Outdoor Dry-Bulb Temperature (°F):     81.83
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.17
  Inlet Dew-Point Temperature (°F):     60.39
    Exit Dry-Bulb Temperature (°F):     59.77
   Exit Dew-Point Temperature (°F):     56.60
       Inlet Relative Humidity (-):     0.510
        Exit Relative Humidity (-):     0.892
    Evaporator Coil Temp Drop (°F):     20.40
              Air Flow Rate (SCFM):    1011.5
         Fan Power Consumption (W):    418.75
(OUTDOOR UNIT)
             Inlet Temperature (°F):    81.83
              Exit Temperature (°F):    98.86
    Condensing Unit Temp Gain (°F):     17.03
         Fan Power Consumption (W):    161.94
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    6860.1
         Sensible Capacity (Btu/h):   22712.7
          Overall Capacity (Btu/h):   29572.8
           Sensible Heat Ratio (-):     0.768
     Overall Power Consumption (W):    2378.4
         NET Cooling EER (Btu/h.W):     12.43
   Evaporator Energy Imbalance (%):      2.82
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    54.38
              Exit Temperature (°F):    68.47
              Inlet Pressure (psia):   169.75
               Exit Pressure (psia):   159.09
               Pressure Drop (psid):    10.66
                Exit Superheat (°F):    17.65
         Exit Sat. Temperature (°F):    50.82
       Evaporator Capacity (Btu/h):   30860.6
(CONDENSER)
             Inlet Temperature (°F):   152.15
              Exit Temperature (°F):    88.98
              Inlet Pressure (psia):   351.90
               Exit Pressure (psia):   349.23
               Pressure Drop (psid):     2.67
               Exit Subcooling (°F):     3.01
        Inlet Sat. Temperature (°F):   104.50
        Condenser Capacity (Btu/h):   37936.6
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    98.78
         Cond Unit Exit Pres (psia):   340.19
     Liq-line Pressure Drop (psid):     14.08
      TXV Upstream Pressure (psia):    326.11
          TXV Pressure Drop (psid):    156.36
              Temperature Drop (°F):     0.98
(COMPRESSOR)
           Suction Temperature (°F):    71.30
         Discharge Temperature (°F):   155.72
            Suction Pressure (psia):   156.67
          Discharge Pressure (psia):   353.17
           Discharge Superheat (°F):    51.22
        Comp Bottom Shell Temp (°F):   112.79
             Mass Flow Rate (lbm/h):   429.95
        Comp Power Consumption (W):    1797.8
          Cond Unit Inlet Temp (°F):    69.82
        Cond Unit Inlet Pres (psia):   157.90
```

```
            HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 05
     FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
                FAULT LEVEL [%]: 35.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.41
   Indoor Dry-Bulb Temperature (°F):    80.13
  Indoor Dew-Point Temperature (°F):    60.53
  Outdoor Dry-Bulb Temperature (°F):    82.02
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    80.13
   Inlet Dew-Point Temperature (°F):    60.53
     Exit Dry-Bulb Temperature (°F):    60.59
    Exit Dew-Point Temperature (°F):    57.29
        Inlet Relative Humidity (-):    0.513
         Exit Relative Humidity (-):    0.889
     Evaporator Coil Temp Drop (°F):    19.54
              Air Flow Rate (SCFM):    1011.7
          Fan Power Consumption (W):   417.92
(OUTDOOR UNIT)
             Inlet Temperature (°F):    82.02
              Exit Temperature (°F):    98.60
     Condensing Unit Temp Gain (°F):    16.59
          Fan Power Consumption (W):   164.00
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    5944.8
         Sensible Capacity (Btu/h):   21764.7
          Overall Capacity (Btu/h):   27709.5
           Sensible Heat Ratio (-):     0.785
      Overall Power Consumption (W):   2486.8
          NET Cooling EER (Btu/h.W):    11.14
    Evaporator Energy Imbalance (%):     0.65
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    52.59
              Exit Temperature (°F):    70.74
              Inlet Pressure (psia):   163.91
               Exit Pressure (psia):   153.57
               Pressure Drop (psid):    10.34
                Exit Superheat (°F):    22.08
          Exit Sat. Temperature (°F):   48.67
        Evaporator Capacity (Btu/h):  28312.7
(CONDENSER)
             Inlet Temperature (°F):   163.41
              Exit Temperature (°F):    87.54
              Inlet Pressure (psia):   368.94
               Exit Pressure (psia):   366.73
               Pressure Drop (psid):     2.22
               Exit Subcooling (°F):     0.79
         Inlet Sat. Temperature (°F):  108.02
         Condenser Capacity (Btu/h):  35699.8
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F): 104.74
           Cond Unit Exit Pres (psia): 357.85
         Liq-line Pressure Drop (psid): 12.98
         TXV Upstream Pressure (psia): 344.87
            TXV Pressure Drop (psid):  180.96
               Temperature Drop (°F):    2.41
(COMPRESSOR)
           Suction Temperature (°F):    74.01
         Discharge Temperature (°F):   167.25
            Suction Pressure (psia):   151.29
          Discharge Pressure (psia):   370.18
           Discharge Superheat (°F):    59.23
          Comp Bottom Shell Temp (°F): 120.64
              Mass Flow Rate (lbm/h):  404.94
         Comp Power Consumption (W):   1904.9
            Cond Unit Inlet Temp (°F):  72.15
          Cond Unit Inlet Pres (psia): 152.51
```

```
            HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 05
     FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
                FAULT LEVEL [%]: 50.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.39
   Indoor Dry-Bulb Temperature (°F):    80.20
  Indoor Dew-Point Temperature (°F):    60.73
  Outdoor Dry-Bulb Temperature (°F):    81.72
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    80.20
   Inlet Dew-Point Temperature (°F):    60.73
     Exit Dry-Bulb Temperature (°F):    61.85
    Exit Dew-Point Temperature (°F):    58.38
        Inlet Relative Humidity (-):    0.515
         Exit Relative Humidity (-):    0.884
     Evaporator Coil Temp Drop (°F):    18.34
              Air Flow Rate (SCFM):    1009.3
          Fan Power Consumption (W):   415.13
(OUTDOOR UNIT)
             Inlet Temperature (°F):    81.72
              Exit Temperature (°F):    97.69
     Condensing Unit Temp Gain (°F):    15.97
          Fan Power Consumption (W):   167.54
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4388.1
         Sensible Capacity (Btu/h):   20391.5
          Overall Capacity (Btu/h):   24779.6
           Sensible Heat Ratio (-):     0.823
      Overall Power Consumption (W):   2913.1
          NET Cooling EER (Btu/h.W):     8.51
    Evaporator Energy Imbalance (%):    -0.04
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    54.38
              Exit Temperature (°F):    71.20
              Inlet Pressure (psia):   168.74
               Exit Pressure (psia):   156.85
               Pressure Drop (psid):    11.90
                Exit Superheat (°F):    21.24
          Exit Sat. Temperature (°F):   49.95
        Evaporator Capacity (Btu/h):  25184.2
(CONDENSER)
             Inlet Temperature (°F):   185.07
              Exit Temperature (°F):    87.89
              Inlet Pressure (psia):   442.19
               Exit Pressure (psia):   440.16
               Pressure Drop (psid):     2.03
               Exit Subcooling (°F):     0.45
         Inlet Sat. Temperature (°F):  121.85
         Condenser Capacity (Btu/h):  33639.6
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F): 118.97
           Cond Unit Exit Pres (psia): 429.57
         Liq-line Pressure Drop (psid): 16.32
         TXV Upstream Pressure (psia): 413.25
            TXV Pressure Drop (psid):  244.51
               Temperature Drop (°F):    2.43
(COMPRESSOR)
           Suction Temperature (°F):    75.24
         Discharge Temperature (°F):   187.52
            Suction Pressure (psia):   154.62
          Discharge Pressure (psia):   443.45
           Discharge Superheat (°F):    65.66
          Comp Bottom Shell Temp (°F): 133.68
              Mass Flow Rate (lbm/h):  398.55
         Comp Power Consumption (W):   2330.4
            Cond Unit Inlet Temp (°F):  72.55
          Cond Unit Inlet Pres (psia): 155.80
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 08
    FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.94
  Indoor Dry-Bulb Temperature (°F):     70.06
 Indoor Dew-Point Temperature (°F):     50.55
 Outdoor Dry-Bulb Temperature (°F):     99.96
AIR SIDE CONDITIONS
 (INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.06
  Inlet Dew-Point Temperature (°F):     50.55
    Exit Dry-Bulb Temperature (°F):     52.05
   Exit Dew-Point Temperature (°F):     48.48
       Inlet Relative Humidity (-):     0.499
        Exit Relative Humidity (-):     0.876
    Evaporator Coil Temp Drop (°F):     18.02
              Air Flow Rate (SCFM):    1012.8
         Fan Power Consumption (W):    419.71
 (OUTDOOR UNIT)
            Inlet Temperature (°F):     99.96
             Exit Temperature (°F):    115.12
    Condensing Unit Temp Gain (°F):     15.17
         Fan Power Consumption (W):    156.18
 (OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2824.2
         Sensible Capacity (Btu/h):   19979.9
          Overall Capacity (Btu/h):   22804.1
           Sensible Heat Ratio (-):     0.876
     Overall Power Consumption (W):    2795.8
         NET Cooling EER (Btu/h.W):      8.16
   Evaporator Energy Imbalance (%):      4.25
REFRIGERANT SIDE CONDITIONS
 (EVAPORATOR)
            Inlet Temperature (°F):     48.15
             Exit Temperature (°F):     56.76
             Inlet Pressure (psia):    153.37
              Exit Pressure (psia):    142.68
              Pressure Drop (psid):     10.69
               Exit Superheat (°F):     12.52
        Exit Sat. Temperature (°F):     44.24
       Evaporator Capacity (Btu/h):   24254.4
 (CONDENSER)
            Inlet Temperature (°F):    177.31
             Exit Temperature (°F):    108.67
             Inlet Pressure (psia):    422.44
              Exit Pressure (psia):    420.53
              Pressure Drop (psid):      1.91
              Exit Subcooling (°F):      6.38
       Inlet Sat. Temperature (°F):    118.31
        Condenser Capacity (Btu/h):   33127.9
 (LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    110.31
        Cond Unit Exit Pres (psia):    414.67
     Liq-line Pressure Drop (psid):     11.28
      TXV Upstream Pressure (psia):    403.39
          TXV Pressure Drop (psid):    250.03
             Temperature Drop (°F):      1.43
 (COMPRESSOR)
          Suction Temperature (°F):     63.60
        Discharge Temperature (°F):    182.60
            Suction Pressure (psia):   140.51
          Discharge Pressure (psia):   423.63
          Discharge Superheat (°F):     64.29
       Comp Bottom Shell Temp (°F):    126.93
            Mass Flow Rate (lbm/h):    376.55
        Comp Power Consumption (W):    2219.9
          Cond Unit Inlet Temp (°F):    59.46
       Cond Unit Inlet Pres (psia):    141.75
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 08
    FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.91
  Indoor Dry-Bulb Temperature (°F):     69.93
 Indoor Dew-Point Temperature (°F):     50.50
 Outdoor Dry-Bulb Temperature (°F):    100.00
AIR SIDE CONDITIONS
 (INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.93
  Inlet Dew-Point Temperature (°F):     50.50
    Exit Dry-Bulb Temperature (°F):     52.32
   Exit Dew-Point Temperature (°F):     48.74
       Inlet Relative Humidity (-):     0.501
        Exit Relative Humidity (-):     0.876
    Evaporator Coil Temp Drop (°F):     17.62
              Air Flow Rate (SCFM):    1011.8
         Fan Power Consumption (W):    419.29
 (OUTDOOR UNIT)
            Inlet Temperature (°F):    100.00
             Exit Temperature (°F):    115.09
    Condensing Unit Temp Gain (°F):     15.09
         Fan Power Consumption (W):    156.90
 (OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2412.2
         Sensible Capacity (Btu/h):   19517.2
          Overall Capacity (Btu/h):   21929.4
           Sensible Heat Ratio (-):     0.890
     Overall Power Consumption (W):    2820.6
         NET Cooling EER (Btu/h.W):      7.78
   Evaporator Energy Imbalance (%):      4.16
REFRIGERANT SIDE CONDITIONS
 (EVAPORATOR)
            Inlet Temperature (°F):     48.44
             Exit Temperature (°F):     57.47
             Inlet Pressure (psia):    154.58
              Exit Pressure (psia):    143.42
              Pressure Drop (psid):     11.16
               Exit Superheat (°F):     12.93
        Exit Sat. Temperature (°F):     44.55
       Evaporator Capacity (Btu/h):   23318.3
 (CONDENSER)
            Inlet Temperature (°F):    178.98
             Exit Temperature (°F):    107.74
             Inlet Pressure (psia):    426.68
              Exit Pressure (psia):    424.71
              Pressure Drop (psid):      1.97
              Exit Subcooling (°F):      1.30
       Inlet Sat. Temperature (°F):    119.08
        Condenser Capacity (Btu/h):   32311.8
 (LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    115.96
        Cond Unit Exit Pres (psia):    417.78
     Liq-line Pressure Drop (psid):     11.56
      TXV Upstream Pressure (psia):    406.23
          TXV Pressure Drop (psid):    251.64
             Temperature Drop (°F):      1.67
 (COMPRESSOR)
          Suction Temperature (°F):     64.02
        Discharge Temperature (°F):    184.58
            Suction Pressure (psia):   141.23
          Discharge Pressure (psia):   427.91
          Discharge Superheat (°F):     65.50
       Comp Bottom Shell Temp (°F):    127.96
            Mass Flow Rate (lbm/h):    377.31
        Comp Power Consumption (W):    2244.4
          Cond Unit Inlet Temp (°F):    60.18
       Cond Unit Inlet Pres (psia):    142.43
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 08
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 35.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.89
  Indoor Dry-Bulb Temperature (°F):     70.00
 Indoor Dew-Point Temperature (°F):     50.53
 Outdoor Dry-Bulb Temperature (°F):     99.97
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.00
  Inlet Dew-Point Temperature (°F):     50.53
    Exit Dry-Bulb Temperature (°F):     52.65
   Exit Dew-Point Temperature (°F):     49.06
       Inlet Relative Humidity (-):     0.500
        Exit Relative Humidity (-):     0.875
    Evaporator Coil Temp Drop (°F):     17.34
             Air Flow Rate (SCFM):     1009.6
         Fan Power Consumption (W):    418.54
(OUTDOOR UNIT)
             Inlet Temperature (°F):    99.97
              Exit Temperature (°F):   115.28
    Condensing Unit Temp Gain (°F):     15.31
         Fan Power Consumption (W):    158.53
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2023.7
         Sensible Capacity (Btu/h):   19176.8
          Overall Capacity (Btu/h):   21200.5
           Sensible Heat Ratio (-):     0.905
     Overall Power Consumption (W):    2945.7
         NET Cooling EER (Btu/h.W):      7.20
   Evaporator Energy Imbalance (%):      3.97
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    48.79
              Exit Temperature (°F):    58.97
              Inlet Pressure (psia):   156.44
               Exit Pressure (psia):   144.36
               Pressure Drop (psid):    12.07
                Exit Superheat (°F):    14.03
        Exit Sat. Temperature (°F):     44.94
       Evaporator Capacity (Btu/h):   22511.8
(CONDENSER)
             Inlet Temperature (°F):   186.29
              Exit Temperature (°F):   105.82
              Inlet Pressure (psia):   446.34
               Exit Pressure (psia):   444.48
               Pressure Drop (psid):     1.86
               Exit Subcooling (°F):     0.40
       Inlet Sat. Temperature (°F):    122.58
        Condenser Capacity (Btu/h):   31800.7
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   120.25
        Cond Unit Exit Pres (psia):    436.51
     Liq-line Pressure Drop (psid):     13.33
       TXV Upstream Pressure (psia):   423.17
           TXV Pressure Drop (psid):   266.74
              Temperature Drop (°F):     1.97
(COMPRESSOR)
           Suction Temperature (°F):    65.59
        Discharge Temperature (°F):    191.44
            Suction Pressure (psia):   142.22
          Discharge Pressure (psia):   447.57
           Discharge Superheat (°F):    68.85
       Comp Bottom Shell Temp (°F):    132.32
            Mass Flow Rate (lbm/h):    375.07
       Comp Power Consumption (W):     2368.6
          Cond Unit Inlet Temp (°F):    61.62
       Cond Unit Inlet Pres (psia):    143.44
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.26
  Indoor Dry-Bulb Temperature (°F):     79.99
 Indoor Dew-Point Temperature (°F):     60.71
 Outdoor Dry-Bulb Temperature (°F):     99.78
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.99
  Inlet Dew-Point Temperature (°F):     60.71
    Exit Dry-Bulb Temperature (°F):     60.77
   Exit Dew-Point Temperature (°F):     57.40
       Inlet Relative Humidity (-):     0.518
        Exit Relative Humidity (-):     0.886
    Evaporator Coil Temp Drop (°F):     19.23
             Air Flow Rate (SCFM):     1005.1
         Fan Power Consumption (W):    417.67
(OUTDOOR UNIT)
             Inlet Temperature (°F):    99.78
              Exit Temperature (°F):   116.85
    Condensing Unit Temp Gain (°F):     17.07
         Fan Power Consumption (W):    156.47
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    6089.6
         Sensible Capacity (Btu/h):   21275.7
          Overall Capacity (Btu/h):   27365.3
           Sensible Heat Ratio (-):     0.777
     Overall Power Consumption (W):    2828.5
         NET Cooling EER (Btu/h.W):      9.68
   Evaporator Energy Imbalance (%):      2.65
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    55.52
              Exit Temperature (°F):    65.92
              Inlet Pressure (psia):   174.23
               Exit Pressure (psia):   162.75
               Pressure Drop (psid):    11.48
                Exit Superheat (°F):    13.70
        Exit Sat. Temperature (°F):     52.22
       Evaporator Capacity (Btu/h):   28538.3
(CONDENSER)
             Inlet Temperature (°F):   174.88
              Exit Temperature (°F):   109.21
              Inlet Pressure (psia):   434.24
               Exit Pressure (psia):   432.08
               Pressure Drop (psid):     2.16
               Exit Subcooling (°F):     8.81
       Inlet Sat. Temperature (°F):    120.44
        Condenser Capacity (Btu/h):   37465.2
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   109.66
        Cond Unit Exit Pres (psia):    424.35
     Liq-line Pressure Drop (psid):     15.16
       TXV Upstream Pressure (psia):   409.20
           TXV Pressure Drop (psid):   234.97
              Temperature Drop (°F):     0.90
(COMPRESSOR)
           Suction Temperature (°F):    70.94
        Discharge Temperature (°F):    179.44
            Suction Pressure (psia):   160.45
          Discharge Pressure (psia):   435.45
           Discharge Superheat (°F):    59.00
       Comp Bottom Shell Temp (°F):    125.32
            Mass Flow Rate (lbm/h):    431.32
       Comp Power Consumption (W):     2254.3
          Cond Unit Inlet Temp (°F):    68.06
       Cond Unit Inlet Pres (psia):    161.60
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.25
  Indoor Dry-Bulb Temperature (°F):     79.95
 Indoor Dew-Point Temperature (°F):     60.81
 Outdoor Dry-Bulb Temperature (°F):     99.72
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.95
  Inlet Dew-Point Temperature (°F):     60.81
    Exit Dry-Bulb Temperature (°F):     60.82
   Exit Dew-Point Temperature (°F):     57.51
       Inlet Relative Humidity (-):     0.521
        Exit Relative Humidity (-):     0.888
    Evaporator Coil Temp Drop (°F):     19.13
              Air Flow Rate (SCFM):    1003.6
         Fan Power Consumption (W):    416.60
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.72
              Exit Temperature (°F):    116.89
    Condensing Unit Temp Gain (°F):     17.17
         Fan Power Consumption (W):    156.59
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    6082.3
         Sensible Capacity (Btu/h):   21139.2
          Overall Capacity (Btu/h):   27221.5
           Sensible Heat Ratio (-):     0.777
     Overall Power Consumption (W):    2836.8
         NET Cooling EER (Btu/h.W):      9.60
   Evaporator Energy Imbalance (%):      2.78
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     55.57
              Exit Temperature (°F):     66.15
              Inlet Pressure (psia):    174.75
               Exit Pressure (psia):    163.13
               Pressure Drop (psid):     11.63
                Exit Superheat (°F):     13.79
        Exit Sat. Temperature (°F):     52.37
       Evaporator Capacity (Btu/h):   28427.6
(CONDENSER)
             Inlet Temperature (°F):    175.51
              Exit Temperature (°F):    108.63
              Inlet Pressure (psia):    435.43
               Exit Pressure (psia):    433.27
               Pressure Drop (psid):      2.16
               Exit Subcooling (°F):      7.95
       Inlet Sat. Temperature (°F):    120.66
        Condenser Capacity (Btu/h):   37389.9
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    110.72
        Cond Unit Exit Pres (psia):    425.47
     Liq-line Pressure Drop (psid):     15.30
      TXV Upstream Pressure (psia):    410.17
           TXV Pressure Drop (psid):    235.41
              Temperature Drop (°F):      1.02
(COMPRESSOR)
           Suction Temperature (°F):     71.11
         Discharge Temperature (°F):    179.86
            Suction Pressure (psia):    160.76
          Discharge Pressure (psia):    436.61
          Discharge Superheat (°F):     59.21
       Comp Bottom Shell Temp (°F):    125.75
             Mass Flow Rate (lbm/h):    432.56
        Comp Power Consumption (W):    2263.6
         Cond Unit Inlet Temp (°F):     68.29
       Cond Unit Inlet Pres (psia):    161.95
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
   FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.48
  Indoor Dry-Bulb Temperature (°F):     80.19
 Indoor Dew-Point Temperature (°F):     60.24
 Outdoor Dry-Bulb Temperature (°F):    100.15
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.19
  Inlet Dew-Point Temperature (°F):     60.24
    Exit Dry-Bulb Temperature (°F):     60.90
   Exit Dew-Point Temperature (°F):     57.63
       Inlet Relative Humidity (-):     0.507
        Exit Relative Humidity (-):     0.890
    Evaporator Coil Temp Drop (°F):     19.28
              Air Flow Rate (SCFM):    1012.3
         Fan Power Consumption (W):    417.42
(OUTDOOR UNIT)
             Inlet Temperature (°F):    100.15
              Exit Temperature (°F):    117.00
    Condensing Unit Temp Gain (°F):     16.85
         Fan Power Consumption (W):    158.47
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4786.5
         Sensible Capacity (Btu/h):   21487.1
          Overall Capacity (Btu/h):   26273.5
           Sensible Heat Ratio (-):     0.818
     Overall Power Consumption (W):    2877.6
         NET Cooling EER (Btu/h.W):      9.13
   Evaporator Energy Imbalance (%):      1.58
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     56.48
              Exit Temperature (°F):     66.67
              Inlet Pressure (psia):    176.46
               Exit Pressure (psia):    164.16
               Pressure Drop (psid):     12.30
                Exit Superheat (°F):     13.91
        Exit Sat. Temperature (°F):     52.76
       Evaporator Capacity (Btu/h):   27120.4
(CONDENSER)
             Inlet Temperature (°F):    177.68
              Exit Temperature (°F):    108.27
              Inlet Pressure (psia):    442.08
               Exit Pressure (psia):    439.81
               Pressure Drop (psid):      2.27
               Exit Subcooling (°F):      2.32
       Inlet Sat. Temperature (°F):    121.83
        Condenser Capacity (Btu/h):   36262.1
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    117.30
        Cond Unit Exit Pres (psia):    430.69
     Liq-line Pressure Drop (psid):     15.93
      TXV Upstream Pressure (psia):    414.76
           TXV Pressure Drop (psid):    238.30
              Temperature Drop (°F):      1.45
(COMPRESSOR)
           Suction Temperature (°F):     71.45
         Discharge Temperature (°F):    182.24
            Suction Pressure (psia):    161.82
          Discharge Pressure (psia):    443.26
          Discharge Superheat (°F):     60.42
       Comp Bottom Shell Temp (°F):    127.19
             Mass Flow Rate (lbm/h):    433.37
        Comp Power Consumption (W):    2301.7
         Cond Unit Inlet Temp (°F):     68.75
       Cond Unit Inlet Pres (psia):    163.01
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 09
 FAULT TYPE: IMPROPER OUTDOOR AIR FLOW FAULT
            FAULT LEVEL [%]: 35.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.52
  Indoor Dry-Bulb Temperature (°F):     80.06
 Indoor Dew-Point Temperature (°F):     60.16
 Outdoor Dry-Bulb Temperature (°F):    100.16
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.06
  Inlet Dew-Point Temperature (°F):     60.16
    Exit Dry-Bulb Temperature (°F):     61.30
   Exit Dew-Point Temperature (°F):     57.90
       Inlet Relative Humidity (-):     0.507
        Exit Relative Humidity (-):     0.886
    Evaporator Coil Temp Drop (°F):     18.76
              Air Flow Rate (SCFM):    1013.4
         Fan Power Consumption (W):    420.60
(OUTDOOR UNIT)
            Inlet Temperature (°F):    100.16
             Exit Temperature (°F):    117.03
    Condensing Unit Temp Gain (°F):     16.86
         Fan Power Consumption (W):    161.21
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4159.9
         Sensible Capacity (Btu/h):   20929.6
          Overall Capacity (Btu/h):   25089.5
           Sensible Heat Ratio (-):     0.834
     Overall Power Consumption (W):    3009.9
         NET Cooling EER (Btu/h.W):      8.34
   Evaporator Energy Imbalance (%):      2.39
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     56.51
             Exit Temperature (°F):     68.77
             Inlet Pressure (psia):    177.64
              Exit Pressure (psia):    164.76
              Pressure Drop (psid):     12.88
               Exit Superheat (°F):     15.79
        Exit Sat. Temperature (°F):     52.98
       Evaporator Capacity (Btu/h):   26135.6
(CONDENSER)
            Inlet Temperature (°F):    185.98
             Exit Temperature (°F):    106.43
             Inlet Pressure (psia):    463.29
              Exit Pressure (psia):    461.18
              Pressure Drop (psid):      2.11
              Exit Subcooling (°F):      0.16
       Inlet Sat. Temperature (°F):    125.51
        Condenser Capacity (Btu/h):   35700.8
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    123.06
        Cond Unit Exit Pres (psia):    451.02
     Liq-line Pressure Drop (psid):     17.37
      TXV Upstream Pressure (psia):    433.65
          TXV Pressure Drop (psid):    256.01
             Temperature Drop (°F):      2.66
(COMPRESSOR)
          Suction Temperature (°F):     73.61
        Discharge Temperature (°F):    189.94
           Suction Pressure (psia):    162.48
         Discharge Pressure (psia):    464.46
          Discharge Superheat (°F):     64.44
       Comp Bottom Shell Temp (°F):    132.84
            Mass Flow Rate (lbm/h):    434.07
        Comp Power Consumption (W):    2428.0
         Cond Unit Inlet Temp (°F):     70.82
       Cond Unit Inlet Pres (psia):    163.67
```

D.4 Improper Indoor Air Flow Fault Tests

Table D.4. List of raw data for improper indoor air flow fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	EF	13.0
4	70	50	82	EF	22.5
4	70	50	82	EF	31.4
5	80	50	82	EF	5.9
5	80	50	82	EF	11.0
5	80	50	82	EF	20.7
5	80	50	82	EF	30.8
8	70	50	100	EF	11.8
8	70	50	100	EF	21.1
8	70	50	100	EF	33.1
9	80	50	100	EF	5.7
9	80	50	100	EF	10.6
9	80	50	100	EF	20.9
9	80	50	100	EF	30.5
12	70	dry	82	EF	14.3
12	70	dry	82	EF	24.1
12	70	dry	82	EF	34.6
13	80	dry	82	EF	6.1
13	80	dry	82	EF	11.0
13	80	dry	82	EF	21.1
13	80	dry	82	EF	30.9

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 04
  FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
            FAULT LEVEL [%]: 13.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.66
   Indoor Dry-Bulb Temperature (°F):    70.10
  Indoor Dew-Point Temperature (°F):    50.32
  Outdoor Dry-Bulb Temperature (°F):    81.48
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    70.10
   Inlet Dew-Point Temperature (°F):    50.32
     Exit Dry-Bulb Temperature (°F):    49.21
    Exit Dew-Point Temperature (°F):    45.81
        Inlet Relative Humidity (-):    0.494
         Exit Relative Humidity (-):    0.880
     Evaporator Coil Temp Drop (°F):    20.89
              Air Flow Rate (SCFM):     896.8
          Fan Power Consumption (W):   397.43
(OUTDOOR UNIT)
                Inlet Temperature (°F):    81.48
                 Exit Temperature (°F):    96.03
     Condensing Unit Temp Gain (°F):    14.55
          Fan Power Consumption (W):   160.92
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   5062.2
          Sensible Capacity (Btu/h):  20497.6
           Overall Capacity (Btu/h):  25559.7
            Sensible Heat Ratio (-):    0.802
      Overall Power Consumption (W):   2272.0
          NET Cooling EER (Btu/h.W):    11.25
    Evaporator Energy Imbalance (%):     4.10
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    45.28
              Exit Temperature (°F):    54.28
              Inlet Pressure (psia):   144.63
               Exit Pressure (psia):   135.93
               Pressure Drop (psid):     8.70
                Exit Superheat (°F):    12.92
          Exit Sat. Temperature (°F):   41.36
       Evaporator Capacity (Btu/h):  27066.9
(CONDENSER)
             Inlet Temperature (°F):   146.75
              Exit Temperature (°F):    89.16
              Inlet Pressure (psia):   329.92
               Exit Pressure (psia):   327.75
               Pressure Drop (psid):     2.17
               Exit Subcooling (°F):     7.97
        Inlet Sat. Temperature (°F):    99.75
        Condenser Capacity (Btu/h):  33922.2
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    89.79
         Cond Unit Exit Pres (psia):   321.99
      Liq-line Pressure Drop (psid):     9.89
        TXV Upstream Pressure (psia):  312.10
           TXV Pressure Drop (psid):   167.47
              Temperature Drop (°F):     0.92
(COMPRESSOR)
           Suction Temperature (°F):    59.44
         Discharge Temperature (°F):   151.29
            Suction Pressure (psia):   133.70
          Discharge Pressure (psia):   331.02
           Discharge Superheat (°F):    51.57
        Comp Bottom Shell Temp (°F):   108.02
             Mass Flow Rate (lbm/h):   369.19
       Comp Power Consumption (W):     1713.6
          Cond Unit Inlet Temp (°F):    56.47
        Cond Unit Inlet Pres (psia):   135.07
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 04
  FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
            FAULT LEVEL [%]: 22.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.66
   Indoor Dry-Bulb Temperature (°F):    69.88
  Indoor Dew-Point Temperature (°F):    50.36
  Outdoor Dry-Bulb Temperature (°F):    81.51
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    69.88
   Inlet Dew-Point Temperature (°F):    50.36
     Exit Dry-Bulb Temperature (°F):    47.94
    Exit Dew-Point Temperature (°F):    44.60
        Inlet Relative Humidity (-):    0.499
         Exit Relative Humidity (-):    0.881
     Evaporator Coil Temp Drop (°F):    21.94
              Air Flow Rate (SCFM):     798.5
          Fan Power Consumption (W):   379.53
(OUTDOOR UNIT)
                Inlet Temperature (°F):    81.51
                 Exit Temperature (°F):    95.83
     Condensing Unit Temp Gain (°F):    14.32
          Fan Power Consumption (W):   161.02
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   5654.4
          Sensible Capacity (Btu/h):  19161.0
           Overall Capacity (Btu/h):  24815.4
            Sensible Heat Ratio (-):    0.772
      Overall Power Consumption (W):   2252.2
          NET Cooling EER (Btu/h.W):    11.02
    Evaporator Energy Imbalance (%):     5.39
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    44.19
              Exit Temperature (°F):    53.03
              Inlet Pressure (psia):   142.16
               Exit Pressure (psia):   133.63
               Pressure Drop (psid):     8.54
                Exit Superheat (°F):    12.68
          Exit Sat. Temperature (°F):   40.36
       Evaporator Capacity (Btu/h):  26629.7
(CONDENSER)
             Inlet Temperature (°F):   146.89
              Exit Temperature (°F):    89.15
              Inlet Pressure (psia):   328.79
               Exit Pressure (psia):   326.68
               Pressure Drop (psid):     2.11
               Exit Subcooling (°F):     7.84
        Inlet Sat. Temperature (°F):    99.50
        Condenser Capacity (Btu/h):  33438.1
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    89.73
         Cond Unit Exit Pres (psia):   321.11
      Liq-line Pressure Drop (psid):     9.51
        TXV Upstream Pressure (psia):  311.60
           TXV Pressure Drop (psid):   169.44
              Temperature Drop (°F):     1.05
(COMPRESSOR)
           Suction Temperature (°F):    58.45
         Discharge Temperature (°F):   151.58
            Suction Pressure (psia):   131.42
          Discharge Pressure (psia):   329.90
           Discharge Superheat (°F):    52.10
        Comp Bottom Shell Temp (°F):   108.11
             Mass Flow Rate (lbm/h):   363.28
       Comp Power Consumption (W):     1711.6
          Cond Unit Inlet Temp (°F):    55.41
        Cond Unit Inlet Pres (psia):   132.74
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 04
      FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 31.4
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.67
   Indoor Dry-Bulb Temperature (°F):     69.88
  Indoor Dew-Point Temperature (°F):     50.36
  Outdoor Dry-Bulb Temperature (°F):     81.53
AIR SIDE CONDITIONS
 (INDOOR UNIT)
      Inlet Dry-Bulb Temperature (°F):     69.88
     Inlet Dew-Point Temperature (°F):     50.36
       Exit Dry-Bulb Temperature (°F):     46.57
      Exit Dew-Point Temperature (°F):     43.28
         Inlet Relative Humidity (-):     0.499
          Exit Relative Humidity (-):     0.882
       Evaporator Coil Temp Drop (°F):     23.31
                  Air Flow Rate (SCFM):     706.7
             Fan Power Consumption (W):    366.17
 (OUTDOOR UNIT)
               Inlet Temperature (°F):     81.53
                Exit Temperature (°F):     95.61
       Condensing Unit Temp Gain (°F):     14.08
             Fan Power Consumption (W):    161.69
 (OVERALL PERFORMANCE)
              Latent Capacity (Btu/h):    6020.6
            Sensible Capacity (Btu/h):   18009.3
             Overall Capacity (Btu/h):   24029.9
              Sensible Heat Ratio (-):     0.749
         Overall Power Consumption (W):    2235.3
            NET Cooling EER (Btu/h.W):     10.75
      Evaporator Energy Imbalance (%):      6.41
REFRIGERANT SIDE CONDITIONS
 (EVAPORATOR)
               Inlet Temperature (°F):     43.09
                Exit Temperature (°F):     51.85
                Inlet Pressure (psia):    139.58
                 Exit Pressure (psia):    131.19
                 Pressure Drop (psid):      8.39
                  Exit Superheat (°F):     12.57
           Exit Sat. Temperature (°F):     39.27
         Evaporator Capacity (Btu/h):   26067.7
 (CONDENSER)
               Inlet Temperature (°F):    147.15
                Exit Temperature (°F):     89.05
                Inlet Pressure (psia):    327.38
                 Exit Pressure (psia):    325.31
                 Pressure Drop (psid):      2.07
                 Exit Subcooling (°F):      7.68
          Inlet Sat. Temperature (°F):     99.19
          Condenser Capacity (Btu/h):   32821.7
 (LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):     89.62
           Cond Unit Exit Pres (psia):    319.92
        Liq-line Pressure Drop (psid):      9.05
         TXV Upstream Pressure (psia):    310.87
             TXV Pressure Drop (psid):    171.29
                Temperature Drop (°F):      1.02
 (COMPRESSOR)
             Suction Temperature (°F):     57.50
           Discharge Temperature (°F):    151.99
              Suction Pressure (psia):    128.97
            Discharge Pressure (psia):    328.45
             Discharge Superheat (°F):     52.83
           Comp Bottom Shell Temp (°F):    108.28
              Mass Flow Rate (lbm/h):    355.70
           Comp Power Consumption (W):    1707.4
            Cond Unit Inlet Temp (°F):     54.24
          Cond Unit Inlet Pres (psia):    130.31
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 05
      FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 5.9
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.45
   Indoor Dry-Bulb Temperature (°F):     79.78
  Indoor Dew-Point Temperature (°F):     60.42
  Outdoor Dry-Bulb Temperature (°F):     81.82
AIR SIDE CONDITIONS
 (INDOOR UNIT)
      Inlet Dry-Bulb Temperature (°F):     79.78
     Inlet Dew-Point Temperature (°F):     60.42
       Exit Dry-Bulb Temperature (°F):     58.63
      Exit Dew-Point Temperature (°F):     55.51
         Inlet Relative Humidity (-):     0.517
          Exit Relative Humidity (-):     0.894
       Evaporator Coil Temp Drop (°F):     21.15
                  Air Flow Rate (SCFM):     951.7
             Fan Power Consumption (W):    402.79
 (OUTDOOR UNIT)
               Inlet Temperature (°F):     81.82
                Exit Temperature (°F):     99.00
       Condensing Unit Temp Gain (°F):     17.18
             Fan Power Consumption (W):    159.33
 (OVERALL PERFORMANCE)
              Latent Capacity (Btu/h):    8202.1
            Sensible Capacity (Btu/h):   22147.6
             Overall Capacity (Btu/h):   30349.7
              Sensible Heat Ratio (-):     0.730
         Overall Power Consumption (W):    2322.4
            NET Cooling EER (Btu/h.W):     13.07
      Evaporator Energy Imbalance (%):      3.84
REFRIGERANT SIDE CONDITIONS
 (EVAPORATOR)
               Inlet Temperature (°F):     53.90
                Exit Temperature (°F):     64.95
                Inlet Pressure (psia):    167.80
                 Exit Pressure (psia):    158.04
                 Pressure Drop (psid):      9.76
                  Exit Superheat (°F):     14.53
           Exit Sat. Temperature (°F):     50.42
         Evaporator Capacity (Btu/h):   31980.4
 (CONDENSER)
               Inlet Temperature (°F):    147.18
                Exit Temperature (°F):     90.77
                Inlet Pressure (psia):    344.89
                 Exit Pressure (psia):    342.27
                 Pressure Drop (psid):      2.63
                 Exit Subcooling (°F):      8.60
          Inlet Sat. Temperature (°F):    103.01
          Condenser Capacity (Btu/h):   38943.4
 (LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):     92.01
           Cond Unit Exit Pres (psia):    334.82
        Liq-line Pressure Drop (psid):     13.92
         TXV Upstream Pressure (psia):    320.91
             TXV Pressure Drop (psid):    153.11
                Temperature Drop (°F):      0.71
 (COMPRESSOR)
             Suction Temperature (°F):     68.23
           Discharge Temperature (°F):    150.93
              Suction Pressure (psia):    155.60
            Discharge Pressure (psia):    346.12
             Discharge Superheat (°F):     47.92
           Comp Bottom Shell Temp (°F):    109.27
              Mass Flow Rate (lbm/h):    432.14
           Comp Power Consumption (W):    1760.3
            Cond Unit Inlet Temp (°F):     66.51
          Cond Unit Inlet Pres (psia):    156.83
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 05
   FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
             FAULT LEVEL [%]: 11.0
RUNNING CONDITIONS
         Barometric Pressure (inHg):    30.42
   Indoor Dry-Bulb Temperature (°F):    79.91
  Indoor Dew-Point Temperature (°F):    60.69
  Outdoor Dry-Bulb Temperature (°F):    81.78
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    79.91
   Inlet Dew-Point Temperature (°F):    60.69
     Exit Dry-Bulb Temperature (°F):    58.25
    Exit Dew-Point Temperature (°F):    55.16
        Inlet Relative Humidity (-):    0.519
         Exit Relative Humidity (-):    0.894
     Evaporator Coil Temp Drop (°F):    21.66
               Air Flow Rate (SCFM):    900.4
          Fan Power Consumption (W):   394.21
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.78
               Exit Temperature (°F):   98.91
     Condensing Unit Temp Gain (°F):    17.13
          Fan Power Consumption (W):   160.03
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):  8742.4
           Sensible Capacity (Btu/h): 21458.4
            Overall Capacity (Btu/h): 30200.9
             Sensible Heat Ratio (-):   0.711
      Overall Power Consumption (W):   2314.4
          NET Cooling EER (Btu/h.W):    13.05
    Evaporator Energy Imbalance (%):     3.92
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   54.04
               Exit Temperature (°F):   64.97
               Inlet Pressure (psia):  167.06
                Exit Pressure (psia):  157.39
                Pressure Drop (psid):    9.68
                 Exit Superheat (°F):   14.81
           Exit Sat. Temperature (°F):  50.16
        Evaporator Capacity (Btu/h):  31843.8
(CONDENSER)
              Inlet Temperature (°F):  147.51
               Exit Temperature (°F):   90.62
               Inlet Pressure (psia):  344.52
                Exit Pressure (psia):  341.93
                Pressure Drop (psid):    2.59
                Exit Subcooling (°F):    8.65
          Inlet Sat. Temperature (°F): 102.93
         Condenser Capacity (Btu/h):  38768.9
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):  91.90
           Cond Unit Exit Pres (psia): 334.52
        Liq-line Pressure Drop (psid):  13.77
         TXV Upstream Pressure (psia): 320.76
             TXV Pressure Drop (psid): 153.69
                Temperature Drop (°F):   0.74
(COMPRESSOR)
            Suction Temperature (°F):   68.26
          Discharge Temperature (°F):  151.26
             Suction Pressure (psia):  154.90
           Discharge Pressure (psia):  345.78
            Discharge Superheat (°F):   48.33
          Comp Bottom Shell Temp (°F): 109.50
              Mass Flow Rate (lbm/h):  429.42
          Comp Power Consumption (W):  1760.2
             Cond Unit Inlet Temp (°F): 66.47
          Cond Unit Inlet Pres (psia): 156.20
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 05
   FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
             FAULT LEVEL [%]: 20.7
RUNNING CONDITIONS
         Barometric Pressure (inHg):    30.42
   Indoor Dry-Bulb Temperature (°F):    80.13
  Indoor Dew-Point Temperature (°F):    60.75
  Outdoor Dry-Bulb Temperature (°F):    81.78
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    80.13
   Inlet Dew-Point Temperature (°F):    60.75
     Exit Dry-Bulb Temperature (°F):    57.22
    Exit Dew-Point Temperature (°F):    54.12
        Inlet Relative Humidity (-):    0.517
         Exit Relative Humidity (-):    0.894
     Evaporator Coil Temp Drop (°F):    22.92
               Air Flow Rate (SCFM):    802.7
          Fan Power Consumption (W):   378.75
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.78
               Exit Temperature (°F):   98.63
     Condensing Unit Temp Gain (°F):    16.85
          Fan Power Consumption (W):   161.04
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):  9197.4
           Sensible Capacity (Btu/h): 20231.3
            Overall Capacity (Btu/h): 29428.7
             Sensible Heat Ratio (-):   0.687
      Overall Power Consumption (W):   2295.9
          NET Cooling EER (Btu/h.W):    12.82
    Evaporator Energy Imbalance (%):     5.17
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   53.17
               Exit Temperature (°F):   63.91
               Inlet Pressure (psia):  164.80
                Exit Pressure (psia):  155.25
                Pressure Drop (psid):    9.55
                 Exit Superheat (°F):   14.57
           Exit Sat. Temperature (°F):  49.33
        Evaporator Capacity (Btu/h):  31430.9
(CONDENSER)
              Inlet Temperature (°F):  147.36
               Exit Temperature (°F):   90.47
               Inlet Pressure (psia):  342.91
                Exit Pressure (psia):  340.39
                Pressure Drop (psid):    2.52
                Exit Subcooling (°F):    8.63
          Inlet Sat. Temperature (°F): 102.58
         Condenser Capacity (Btu/h):  38310.3
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):  91.65
           Cond Unit Exit Pres (psia): 333.28
        Liq-line Pressure Drop (psid):  13.40
         TXV Upstream Pressure (psia): 319.89
             TXV Pressure Drop (psid): 155.09
                Temperature Drop (°F):   0.68
(COMPRESSOR)
            Suction Temperature (°F):   67.36
          Discharge Temperature (°F):  151.24
             Suction Pressure (psia):  152.78
           Discharge Pressure (psia):  344.17
            Discharge Superheat (°F):   48.66
          Comp Bottom Shell Temp (°F): 109.29
              Mass Flow Rate (lbm/h):  423.49
          Comp Power Consumption (W):  1756.1
             Cond Unit Inlet Temp (°F): 65.39
          Cond Unit Inlet Pres (psia): 154.07
```

```
                HEAT PUMP FAULT TEST SUMMARY

               INDOOR/OUTDOOR CONDITION #: 05
        FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
                   FAULT LEVEL [%]: 30.8
RUNNING CONDITIONS
          Barometric Pressure (inHg):     30.42
   Indoor Dry-Bulb Temperature (°F):      80.10
  Indoor Dew-Point Temperature (°F):      60.35
  Outdoor Dry-Bulb Temperature (°F):      81.85
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):      80.10
   Inlet Dew-Point Temperature (°F):      60.35
     Exit Dry-Bulb Temperature (°F):      55.52
    Exit Dew-Point Temperature (°F):      52.38
        Inlet Relative Humidity (-):      0.510
         Exit Relative Humidity (-):      0.892
     Evaporator Coil Temp Drop (°F):      24.59
               Air Flow Rate (SCFM):      700.3
          Fan Power Consumption (W):     362.56
(OUTDOOR UNIT)
               Inlet Temperature (°F):    81.85
                Exit Temperature (°F):    98.34
     Condensing Unit Temp Gain (°F):      16.49
          Fan Power Consumption (W):     161.65
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):     9318.7
          Sensible Capacity (Btu/h):    18927.9
           Overall Capacity (Btu/h):    28246.6
            Sensible Heat Ratio (-):      0.670
      Overall Power Consumption (W):     2276.7
          NET Cooling EER (Btu/h.W):      12.41
    Evaporator Energy Imbalance (%):       6.42
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):    51.59
                Exit Temperature (°F):    62.07
               Inlet Pressure (psia):    161.18
                Exit Pressure (psia):    151.80
                Pressure Drop (psid):      9.39
                 Exit Superheat (°F):     14.11
          Exit Sat. Temperature (°F):     47.96
        Evaporator Capacity (Btu/h):    30573.2
(CONDENSER)
               Inlet Temperature (°F):   147.33
                Exit Temperature (°F):    90.46
               Inlet Pressure (psia):    341.23
                Exit Pressure (psia):    338.77
                Pressure Drop (psid):      2.47
                Exit Subcooling (°F):      8.44
         Inlet Sat. Temperature (°F):    102.22
         Condenser Capacity (Btu/h):    37392.4
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):     91.54
          Cond Unit Exit Pres (psia):    331.94
        Liq-line Pressure Drop (psid):    12.71
        TXV Upstream Pressure (psia):    319.23
           TXV Pressure Drop (psid):     158.05
               Temperature Drop (°F):      0.68
(COMPRESSOR)
            Suction Temperature (°F):     65.87
          Discharge Temperature (°F):    151.33
              Suction Pressure (psia):   149.30
            Discharge Pressure (psia):   342.45
             Discharge Superheat (°F):    49.11
          Comp Bottom Shell Temp (°F):   108.99
               Mass Flow Rate (lbm/h):   412.66
         Comp Power Consumption (W):     1752.5
           Cond Unit Inlet Temp (°F):     63.67
         Cond Unit Inlet Pres (psia):    150.63
```

```
                HEAT PUMP FAULT TEST SUMMARY

               INDOOR/OUTDOOR CONDITION #: 08
        FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
                   FAULT LEVEL [%]: 11.8
RUNNING CONDITIONS
          Barometric Pressure (inHg):     29.90
   Indoor Dry-Bulb Temperature (°F):      70.16
  Indoor Dew-Point Temperature (°F):      50.57
  Outdoor Dry-Bulb Temperature (°F):      99.98
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):      70.16
   Inlet Dew-Point Temperature (°F):      50.57
     Exit Dry-Bulb Temperature (°F):      50.93
    Exit Dew-Point Temperature (°F):      47.41
        Inlet Relative Humidity (-):      0.498
         Exit Relative Humidity (-):      0.877
     Evaporator Coil Temp Drop (°F):      19.23
               Air Flow Rate (SCFM):      899.5
          Fan Power Consumption (W):     396.40
(OUTDOOR UNIT)
               Inlet Temperature (°F):    99.98
                Exit Temperature (°F):   114.81
     Condensing Unit Temp Gain (°F):      14.83
          Fan Power Consumption (W):     155.01
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):     3768.2
          Sensible Capacity (Btu/h):    18934.7
           Overall Capacity (Btu/h):    22702.9
            Sensible Heat Ratio (-):      0.834
      Overall Power Consumption (W):     2767.6
          NET Cooling EER (Btu/h.W):       8.20
    Evaporator Energy Imbalance (%):       3.68
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):    46.93
                Exit Temperature (°F):    56.08
               Inlet Pressure (psia):    151.09
                Exit Pressure (psia):    140.55
                Pressure Drop (psid):     10.54
                 Exit Superheat (°F):     12.74
          Exit Sat. Temperature (°F):     43.34
        Evaporator Capacity (Btu/h):    23981.7
(CONDENSER)
               Inlet Temperature (°F):   177.63
                Exit Temperature (°F):   109.21
               Inlet Pressure (psia):    420.37
                Exit Pressure (psia):    418.50
                Pressure Drop (psid):      1.87
                Exit Subcooling (°F):      7.03
         Inlet Sat. Temperature (°F):    117.93
         Condenser Capacity (Btu/h):    32730.5
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):    109.30
          Cond Unit Exit Pres (psia):    412.73
        Liq-line Pressure Drop (psid):    10.81
        TXV Upstream Pressure (psia):    401.92
           TXV Pressure Drop (psid):     250.83
               Temperature Drop (°F):      1.45
(COMPRESSOR)
            Suction Temperature (°F):     63.28
          Discharge Temperature (°F):    183.23
              Suction Pressure (psia):   138.38
            Discharge Pressure (psia):   421.42
             Discharge Superheat (°F):    65.33
          Comp Bottom Shell Temp (°F):   127.81
               Mass Flow Rate (lbm/h):   368.91
         Comp Power Consumption (W):     2216.2
           Cond Unit Inlet Temp (°F):     58.86
         Cond Unit Inlet Pres (psia):    139.63
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 08
   FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 21.1
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.90
  Indoor Dry-Bulb Temperature (°F):     69.90
 Indoor Dew-Point Temperature (°F):     50.19
 Outdoor Dry-Bulb Temperature (°F):     99.98
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.90
  Inlet Dew-Point Temperature (°F):     50.19
    Exit Dry-Bulb Temperature (°F):     49.60
   Exit Dew-Point Temperature (°F):     46.17
       Inlet Relative Humidity (-):     0.495
        Exit Relative Humidity (-):     0.879
    Evaporator Coil Temp Drop (°F):     20.31
              Air Flow Rate (SCFM):     802.5
          Fan Power Consumption (W):   378.55
(OUTDOOR UNIT)
                Inlet Temperature (°F):     99.98
                 Exit Temperature (°F):    114.52
    Condensing Unit Temp Gain (°F):     14.54
          Fan Power Consumption (W):   155.02
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4165.5
         Sensible Capacity (Btu/h):   17831.2
          Overall Capacity (Btu/h):   21996.7
           Sensible Heat Ratio (-):     0.811
      Overall Power Consumption (W):   2743.8
        NET Cooling EER (Btu/h.W):      8.02
   Evaporator Energy Imbalance (%):      4.94
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     45.87
              Exit Temperature (°F):     54.66
              Inlet Pressure (psia):    148.35
               Exit Pressure (psia):    137.98
               Pressure Drop (psid):     10.37
                Exit Superheat (°F):     12.41
         Exit Sat. Temperature (°F):     42.24
       Evaporator Capacity (Btu/h):   23537.2
(CONDENSER)
             Inlet Temperature (°F):    177.89
              Exit Temperature (°F):    109.09
              Inlet Pressure (psia):    418.63
               Exit Pressure (psia):    416.80
               Pressure Drop (psid):      1.83
               Exit Subcooling (°F):      6.91
        Inlet Sat. Temperature (°F):    117.61
        Condenser Capacity (Btu/h):   32224.8
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    109.15
          Cond Unit Exit Pres (psia):    411.30
      Liq-line Pressure Drop (psid):     10.38
        TXV Upstream Pressure (psia):    400.92
           TXV Pressure Drop (psid):    252.58
              Temperature Drop (°F):      1.53
(COMPRESSOR)
           Suction Temperature (°F):     62.26
         Discharge Temperature (°F):    183.67
            Suction Pressure (psia):    135.82
          Discharge Pressure (psia):    419.70
           Discharge Superheat (°F):     66.09
        Comp Bottom Shell Temp (°F):    128.00
             Mass Flow Rate (lbm/h):    362.12
         Comp Power Consumption (W):    2210.3
          Cond Unit Inlet Temp (°F):     57.58
        Cond Unit Inlet Pres (psia):    137.07
```

```
           HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 08
   FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 33.1
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.09
  Indoor Dry-Bulb Temperature (°F):     69.98
 Indoor Dew-Point Temperature (°F):     50.47
 Outdoor Dry-Bulb Temperature (°F):     99.87
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.98
  Inlet Dew-Point Temperature (°F):     50.47
    Exit Dry-Bulb Temperature (°F):     48.34
   Exit Dew-Point Temperature (°F):     44.95
       Inlet Relative Humidity (-):     0.499
        Exit Relative Humidity (-):     0.880
    Evaporator Coil Temp Drop (°F):     21.64
              Air Flow Rate (SCFM):     695.1
          Fan Power Consumption (W):   363.59
(OUTDOOR UNIT)
                Inlet Temperature (°F):     99.87
                 Exit Temperature (°F):    114.06
    Condensing Unit Temp Gain (°F):     14.19
          Fan Power Consumption (W):   156.34
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4841.2
         Sensible Capacity (Btu/h):   16453.2
          Overall Capacity (Btu/h):   21294.4
           Sensible Heat Ratio (-):     0.773
      Overall Power Consumption (W):   2722.1
        NET Cooling EER (Btu/h.W):      7.82
   Evaporator Energy Imbalance (%):      5.90
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     44.60
              Exit Temperature (°F):     53.07
              Inlet Pressure (psia):    145.23
               Exit Pressure (psia):    135.02
               Pressure Drop (psid):     10.21
                Exit Superheat (°F):     12.11
         Exit Sat. Temperature (°F):     40.97
       Evaporator Capacity (Btu/h):   23015.4
(CONDENSER)
             Inlet Temperature (°F):    178.04
              Exit Temperature (°F):    108.78
              Inlet Pressure (psia):    415.86
               Exit Pressure (psia):    414.08
               Pressure Drop (psid):      1.78
               Exit Subcooling (°F):      6.89
        Inlet Sat. Temperature (°F):    117.10
        Condenser Capacity (Btu/h):   31624.7
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    108.72
          Cond Unit Exit Pres (psia):    408.91
      Liq-line Pressure Drop (psid):      9.79
        TXV Upstream Pressure (psia):    399.12
           TXV Pressure Drop (psid):    253.88
              Temperature Drop (°F):      1.51
(COMPRESSOR)
           Suction Temperature (°F):     61.15
         Discharge Temperature (°F):    184.05
            Suction Pressure (psia):    132.86
          Discharge Pressure (psia):    416.96
           Discharge Superheat (°F):     66.98
        Comp Bottom Shell Temp (°F):    127.87
             Mass Flow Rate (lbm/h):    353.69
         Comp Power Consumption (W):    2202.1
          Cond Unit Inlet Temp (°F):     56.23
        Cond Unit Inlet Pres (psia):    134.13
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
    FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 5.7
RUNNING CONDITIONS
        Barometric Pressure (inHg):      30.56
  Indoor Dry-Bulb Temperature (°F):      79.98
 Indoor Dew-Point Temperature (°F):      60.42
 Outdoor Dry-Bulb Temperature (°F):      99.80
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):      79.98
  Inlet Dew-Point Temperature (°F):      60.42
    Exit Dry-Bulb Temperature (°F):      60.14
   Exit Dew-Point Temperature (°F):      56.68
       Inlet Relative Humidity (-):      0.513
        Exit Relative Humidity (-):      0.883
    Evaporator Coil Temp Drop (°F):      19.84
              Air Flow Rate (SCFM):      954.5
         Fan Power Consumption (W):     408.00
(OUTDOOR UNIT)
                 Inlet Temperature (°F):      99.80
                  Exit Temperature (°F):     116.56
    Condensing Unit Temp Gain (°F):      16.76
         Fan Power Consumption (W):     157.62
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):     6365.0
         Sensible Capacity (Btu/h):    20839.0
          Overall Capacity (Btu/h):    27204.0
           Sensible Heat Ratio (-):      0.766
     Overall Power Consumption (W):     2811.2
         NET Cooling EER (Btu/h.W):       9.68
   Evaporator Energy Imbalance (%):       2.41
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):      55.25
             Exit Temperature (°F):      65.66
             Inlet Pressure (psia):     172.96
              Exit Pressure (psia):     161.52
              Pressure Drop (psid):      11.44
               Exit Superheat (°F):      13.90
       Exit Sat. Temperature (°F):      51.76
      Evaporator Capacity (Btu/h):    28293.3
(CONDENSER)
            Inlet Temperature (°F):     174.95
             Exit Temperature (°F):     109.10
             Inlet Pressure (psia):     432.63
              Exit Pressure (psia):     430.48
              Pressure Drop (psid):       2.16
              Exit Subcooling (°F):       8.37
       Inlet Sat. Temperature (°F):     120.15
       Condenser Capacity (Btu/h):    37143.5
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     109.81
        Cond Unit Exit Pres (psia):     422.79
     Liq-line Pressure Drop (psid):      15.08
      TXV Upstream Pressure (psia):     407.71
          TXV Pressure Drop (psid):     234.76
             Temperature Drop (°F):       1.07
(COMPRESSOR)
          Suction Temperature (°F):      70.78
        Discharge Temperature (°F):     179.44
           Suction Pressure (psia):     159.22
         Discharge Pressure (psia):     433.79
          Discharge Superheat (°F):      59.29
       Comp Bottom Shell Temp (°F):     125.49
            Mass Flow Rate (lbm/h):     427.66
        Comp Power Consumption (W):     2245.6
         Cond Unit Inlet Temp (°F):      67.72
       Cond Unit Inlet Pres (psia):     160.44
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
    FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 10.6
RUNNING CONDITIONS
        Barometric Pressure (inHg):      30.61
  Indoor Dry-Bulb Temperature (°F):      79.94
 Indoor Dew-Point Temperature (°F):      60.49
 Outdoor Dry-Bulb Temperature (°F):      99.80
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):      79.94
  Inlet Dew-Point Temperature (°F):      60.49
    Exit Dry-Bulb Temperature (°F):      59.71
   Exit Dew-Point Temperature (°F):      56.32
       Inlet Relative Humidity (-):      0.515
        Exit Relative Humidity (-):      0.885
    Evaporator Coil Temp Drop (°F):      20.23
              Air Flow Rate (SCFM):      904.7
         Fan Power Consumption (W):     398.80
(OUTDOOR UNIT)
                 Inlet Temperature (°F):      99.80
                  Exit Temperature (°F):     116.47
    Condensing Unit Temp Gain (°F):      16.67
         Fan Power Consumption (W):     157.67
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):     6676.2
         Sensible Capacity (Btu/h):    20142.3
          Overall Capacity (Btu/h):    26818.5
           Sensible Heat Ratio (-):      0.751
     Overall Power Consumption (W):     2799.3
         NET Cooling EER (Btu/h.W):       9.58
   Evaporator Energy Imbalance (%):       3.19
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):      54.89
             Exit Temperature (°F):      65.19
             Inlet Pressure (psia):     172.02
              Exit Pressure (psia):     160.62
              Pressure Drop (psid):      11.40
               Exit Superheat (°F):      13.78
       Exit Sat. Temperature (°F):      51.41
      Evaporator Capacity (Btu/h):    28114.9
(CONDENSER)
            Inlet Temperature (°F):     175.04
             Exit Temperature (°F):     109.09
             Inlet Pressure (psia):     432.01
              Exit Pressure (psia):     429.88
              Pressure Drop (psid):       2.13
              Exit Subcooling (°F):       8.30
       Inlet Sat. Temperature (°F):     120.04
       Condenser Capacity (Btu/h):    36941.1
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     109.79
        Cond Unit Exit Pres (psia):     422.35
     Liq-line Pressure Drop (psid):      14.90
      TXV Upstream Pressure (psia):     407.45
          TXV Pressure Drop (psid):     235.43
             Temperature Drop (°F):       1.13
(COMPRESSOR)
          Suction Temperature (°F):      70.45
        Discharge Temperature (°F):     179.58
           Suction Pressure (psia):     158.28
         Discharge Pressure (psia):     433.22
          Discharge Superheat (°F):      59.54
       Comp Bottom Shell Temp (°F):     125.62
            Mass Flow Rate (lbm/h):     424.96
        Comp Power Consumption (W):     2242.8
         Cond Unit Inlet Temp (°F):      67.38
       Cond Unit Inlet Pres (psia):     159.50
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
  FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 20.9
RUNNING CONDITIONS
        Barometric Pressure (inHg):     31.02
  Indoor Dry-Bulb Temperature (°F):     80.18
 Indoor Dew-Point Temperature (°F):     60.36
 Outdoor Dry-Bulb Temperature (°F):    100.02
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.18
  Inlet Dew-Point Temperature (°F):     60.36
    Exit Dry-Bulb Temperature (°F):     58.65
   Exit Dew-Point Temperature (°F):     55.15
       Inlet Relative Humidity (-):     0.509
        Exit Relative Humidity (-):     0.881
    Evaporator Coil Temp Drop (°F):     21.53
              Air Flow Rate (SCFM):     800.5
         Fan Power Consumption (W):    374.75
(OUTDOOR UNIT)
             Inlet Temperature (°F):   100.02
              Exit Temperature (°F):   116.29
    Condensing Unit Temp Gain (°F):     16.27
         Fan Power Consumption (W):    158.90
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    7142.4
         Sensible Capacity (Btu/h):   18951.3
          Overall Capacity (Btu/h):   26093.7
           Sensible Heat Ratio (-):     0.726
     Overall Power Consumption (W):    2768.3
         NET Cooling EER (Btu/h.W):      9.43
   Evaporator Energy Imbalance (%):      4.47
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     54.28
             Exit Temperature (°F):     64.37
             Inlet Pressure (psia):    169.77
              Exit Pressure (psia):    158.32
              Pressure Drop (psid):     11.45
               Exit Superheat (°F):     13.84
        Exit Sat. Temperature (°F):     50.53
       Evaporator Capacity (Btu/h):   27706.7
(CONDENSER)
            Inlet Temperature (°F):    175.00
             Exit Temperature (°F):    109.71
             Inlet Pressure (psia):    429.88
              Exit Pressure (psia):    427.73
              Pressure Drop (psid):      2.15
              Exit Subcooling (°F):      7.81
       Inlet Sat. Temperature (°F):    119.66
        Condenser Capacity (Btu/h):   36399.8
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   109.93
        Cond Unit Exit Pres (psia):    420.37
      Liq-line Pressure Drop (psid):    14.05
       TXV Upstream Pressure (psia):   406.32
          TXV Pressure Drop (psid):    236.55
             Temperature Drop (°F):      1.00
(COMPRESSOR)
          Suction Temperature (°F):     69.80
        Discharge Temperature (°F):    179.59
           Suction Pressure (psia):    156.16
         Discharge Pressure (psia):    430.84
          Discharge Superheat (°F):     59.98
       Comp Bottom Shell Temp (°F):    125.09
           Mass Flow Rate (lbm/h):     418.60
       Comp Power Consumption (W):     2234.6
          Cond Unit Inlet Temp (°F):    66.49
       Cond Unit Inlet Pres (psia):    157.32
```

```
            HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 09
  FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
               FAULT LEVEL [%]: 30.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.96
  Indoor Dry-Bulb Temperature (°F):     79.99
 Indoor Dew-Point Temperature (°F):     60.65
 Outdoor Dry-Bulb Temperature (°F):    100.03
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.99
  Inlet Dew-Point Temperature (°F):     60.65
    Exit Dry-Bulb Temperature (°F):     57.44
   Exit Dew-Point Temperature (°F):     54.15
       Inlet Relative Humidity (-):     0.517
        Exit Relative Humidity (-):     0.887
    Evaporator Coil Temp Drop (°F):     22.55
              Air Flow Rate (SCFM):     703.4
         Fan Power Consumption (W):    360.50
(OUTDOOR UNIT)
             Inlet Temperature (°F):   100.03
              Exit Temperature (°F):   116.15
    Condensing Unit Temp Gain (°F):     16.12
         Fan Power Consumption (W):    157.34
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    7755.3
         Sensible Capacity (Btu/h):   17438.6
          Overall Capacity (Btu/h):   25193.9
           Sensible Heat Ratio (-):     0.692
     Overall Power Consumption (W):    2743.9
         NET Cooling EER (Btu/h.W):      9.18
   Evaporator Energy Imbalance (%):      6.11
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     53.18
             Exit Temperature (°F):     63.28
             Inlet Pressure (psia):    166.59
              Exit Pressure (psia):    155.57
              Pressure Drop (psid):     11.02
               Exit Superheat (°F):     13.82
        Exit Sat. Temperature (°F):     49.46
       Evaporator Capacity (Btu/h):   27216.3
(CONDENSER)
            Inlet Temperature (°F):    175.79
             Exit Temperature (°F):    109.36
             Inlet Pressure (psia):    428.84
              Exit Pressure (psia):    426.75
              Pressure Drop (psid):      2.08
              Exit Subcooling (°F):      8.04
       Inlet Sat. Temperature (°F):    119.47
        Condenser Capacity (Btu/h):   35894.1
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   109.58
        Cond Unit Exit Pres (psia):    419.72
      Liq-line Pressure Drop (psid):    13.45
       TXV Upstream Pressure (psia):   406.27
          TXV Pressure Drop (psid):    239.68
             Temperature Drop (°F):      1.05
(COMPRESSOR)
          Suction Temperature (°F):     68.90
        Discharge Temperature (°F):    180.61
           Suction Pressure (psia):    153.34
         Discharge Pressure (psia):    429.86
          Discharge Superheat (°F):     61.17
       Comp Bottom Shell Temp (°F):    125.73
           Mass Flow Rate (lbm/h):     410.36
       Comp Power Consumption (W):     2226.1
          Cond Unit Inlet Temp (°F):    65.41
       Cond Unit Inlet Pres (psia):    154.57
```

```
                HEAT PUMP FAULT TEST SUMMARY

               INDOOR/OUTDOOR CONDITION #: 12
         FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
                    FAULT LEVEL [%]: 14.3
RUNNING CONDITIONS
        Barometric Pressure (inHg):      30.64
  Indoor Dry-Bulb Temperature (°F):      69.60
 Indoor Dew-Point Temperature (°F):      32.01
 Outdoor Dry-Bulb Temperature (°F):      81.74
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):      69.60
  Inlet Dew-Point Temperature (°F):      32.01
    Exit Dry-Bulb Temperature (°F):      44.63
   Exit Dew-Point Temperature (°F):      32.13
       Inlet Relative Humidity (-):      0.248
        Exit Relative Humidity (-):      0.613
    Evaporator Coil Temp Drop (°F):      24.97
              Air Flow Rate (SCFM):      902.4
         Fan Power Consumption (W):     407.11
(OUTDOOR UNIT)
              Inlet Temperature (°F):    81.74
               Exit Temperature (°F):    95.30
    Condensing Unit Temp Gain (°F):      13.56
         Fan Power Consumption (W):     163.35
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):        0.0
         Sensible Capacity (Btu/h):    24498.9
          Overall Capacity (Btu/h):    24415.6
           Sensible Heat Ratio (-):      1.000
     Overall Power Consumption (W):     2277.9
         NET Cooling EER (Btu/h.W):      10.72
    Evaporator Energy Imbalance (%):      0.59
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):    42.72
               Exit Temperature (°F):    49.80
               Inlet Pressure (psia):   135.77
                Exit Pressure (psia):   127.33
                Pressure Drop (psid):     8.44
                 Exit Superheat (°F):    12.26
           Exit Sat. Temperature (°F):   37.54
        Evaporator Capacity (Btu/h):   24970.9
(CONDENSER)
              Inlet Temperature (°F):   147.50
               Exit Temperature (°F):    89.63
               Inlet Pressure (psia):   325.66
                Exit Pressure (psia):   323.66
                Pressure Drop (psid):     2.01
                Exit Subcooling (°F):     7.17
          Inlet Sat. Temperature (°F):   98.81
         Condenser Capacity (Btu/h):   31871.9
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):   89.82
           Cond Unit Exit Pres (psia):  318.55
        Liq-line Pressure Drop (psid):    8.56
         TXV Upstream Pressure (psia):  309.99
             TXV Pressure Drop (psid):  174.22
                Temperature Drop (°F):    0.97
(COMPRESSOR)
             Suction Temperature (°F):   55.95
           Discharge Temperature (°F):  152.74
               Suction Pressure (psia): 125.04
             Discharge Pressure (psia): 326.47
              Discharge Superheat (°F):  54.02
          Comp Bottom Shell Temp (°F):  108.47
               Mass Flow Rate (lbm/h):  344.62
         Comp Power Consumption (W):    1707.5
            Cond Unit Inlet Temp (°F):   52.41
          Cond Unit Inlet Pres (psia):  126.42
```

```
                HEAT PUMP FAULT TEST SUMMARY

               INDOOR/OUTDOOR CONDITION #: 12
         FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
                    FAULT LEVEL [%]: 24.1
RUNNING CONDITIONS
        Barometric Pressure (inHg):      30.63
  Indoor Dry-Bulb Temperature (°F):      69.98
 Indoor Dew-Point Temperature (°F):      32.01
 Outdoor Dry-Bulb Temperature (°F):      81.62
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):      69.98
  Inlet Dew-Point Temperature (°F):      32.01
    Exit Dry-Bulb Temperature (°F):      43.13
   Exit Dew-Point Temperature (°F):      32.15
       Inlet Relative Humidity (-):      0.244
        Exit Relative Humidity (-):      0.649
    Evaporator Coil Temp Drop (°F):      26.85
              Air Flow Rate (SCFM):      799.8
         Fan Power Consumption (W):     387.00
(OUTDOOR UNIT)
              Inlet Temperature (°F):    81.62
               Exit Temperature (°F):    94.84
    Condensing Unit Temp Gain (°F):      13.22
         Fan Power Consumption (W):     162.95
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):        0.0
         Sensible Capacity (Btu/h):    23354.3
          Overall Capacity (Btu/h):    23271.3
           Sensible Heat Ratio (-):      1.000
     Overall Power Consumption (W):     2251.6
         NET Cooling EER (Btu/h.W):      10.34
    Evaporator Energy Imbalance (%):      2.56
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):    41.45
               Exit Temperature (°F):    48.04
               Inlet Pressure (psia):   132.52
                Exit Pressure (psia):   124.26
                Pressure Drop (psid):     8.26
                 Exit Superheat (°F):    11.91
           Exit Sat. Temperature (°F):   36.12
        Evaporator Capacity (Btu/h):   24278.6
(CONDENSER)
              Inlet Temperature (°F):   147.74
               Exit Temperature (°F):    89.47
               Inlet Pressure (psia):   323.32
                Exit Pressure (psia):   321.34
                Pressure Drop (psid):     1.98
                Exit Subcooling (°F):     6.90
          Inlet Sat. Temperature (°F):   98.28
         Condenser Capacity (Btu/h):   31110.4
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):   89.62
           Cond Unit Exit Pres (psia):  316.50
        Liq-line Pressure Drop (psid):    7.99
         TXV Upstream Pressure (psia):  308.51
             TXV Pressure Drop (psid):  175.99
                Temperature Drop (°F):    1.10
(COMPRESSOR)
             Suction Temperature (°F):   54.66
           Discharge Temperature (°F):  153.19
               Suction Pressure (psia): 121.94
             Discharge Pressure (psia): 324.10
              Discharge Superheat (°F):  55.01
          Comp Bottom Shell Temp (°F):  108.78
               Mass Flow Rate (lbm/h):  335.22
         Comp Power Consumption (W):    1701.6
            Cond Unit Inlet Temp (°F):   50.95
          Cond Unit Inlet Pres (psia):  123.33
          HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 12
  FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
            FAULT LEVEL [%]: 34.6
RUNNING CONDITIONS
           Barometric Pressure (inHg):     30.62
   Indoor Dry-Bulb Temperature (°F):      70.02
  Indoor Dew-Point Temperature (°F):      32.01
  Outdoor Dry-Bulb Temperature (°F):      81.60
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):      70.02
   Inlet Dew-Point Temperature (°F):      32.01
     Exit Dry-Bulb Temperature (°F):      40.98
    Exit Dew-Point Temperature (°F):      32.14
        Inlet Relative Humidity (-):      0.244
         Exit Relative Humidity (-):      0.705
     Evaporator Coil Temp Drop (°F):      29.04
               Air Flow Rate (SCFM):      695.9
          Fan Power Consumption (W):     362.25
(OUTDOOR UNIT)
              Inlet Temperature (°F):     81.60
               Exit Temperature (°F):     94.44
     Condensing Unit Temp Gain (°F):      12.84
          Fan Power Consumption (W):     160.84
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):        0.0
          Sensible Capacity (Btu/h):    21976.9
           Overall Capacity (Btu/h):    21908.4
            Sensible Heat Ratio (-):      1.000
      Overall Power Consumption (W):     2214.9
          NET Cooling EER (Btu/h.W):       9.89
    Evaporator Energy Imbalance (%):       4.50
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):     39.49
               Exit Temperature (°F):     45.62
              Inlet Pressure (psia):     127.80
               Exit Pressure (psia):     119.94
                Pressure Drop (psid):      7.87
                 Exit Superheat (°F):     11.53
           Exit Sat. Temperature (°F):    34.10
         Evaporator Capacity (Btu/h):   23319.9
(CONDENSER)
              Inlet Temperature (°F):    148.38
               Exit Temperature (°F):     89.31
              Inlet Pressure (psia):     320.82
               Exit Pressure (psia):     318.98
                Pressure Drop (psid):      1.84
                Exit Subcooling (°F):      6.69
          Inlet Sat. Temperature (°F):    97.72
          Condenser Capacity (Btu/h):   30064.2
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):     89.37
          Cond Unit Exit Pres (psia):    314.52
      Liq-line Pressure Drop (psid):       7.27
        TXV Upstream Pressure (psia):    307.24
            TXV Pressure Drop (psid):    179.44
               Temperature Drop (°F):      1.17
(COMPRESSOR)
           Suction Temperature (°F):      52.91
         Discharge Temperature (°F):     154.13
             Suction Pressure (psia):    117.65
           Discharge Pressure (psia):    321.63
            Discharge Superheat (°F):     56.51
          Comp Bottom Shell Temp (°F):   109.23
               Mass Flow Rate (lbm/h):   322.26
         Comp Power Consumption (W):     1691.8
            Cond Unit Inlet Temp (°F):    48.80
          Cond Unit Inlet Pres (psia):   119.02
```

```
          HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 13
  FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
             FAULT LEVEL [%]: 6.1
RUNNING CONDITIONS
           Barometric Pressure (inHg):     30.02
   Indoor Dry-Bulb Temperature (°F):      80.15
  Indoor Dew-Point Temperature (°F):      34.99
  Outdoor Dry-Bulb Temperature (°F):      81.90
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):      80.15
   Inlet Dew-Point Temperature (°F):      34.99
     Exit Dry-Bulb Temperature (°F):      52.80
    Exit Dew-Point Temperature (°F):      35.48
        Inlet Relative Humidity (-):      0.196
         Exit Relative Humidity (-):      0.516
     Evaporator Coil Temp Drop (°F):      27.35
               Air Flow Rate (SCFM):      950.5
          Fan Power Consumption (W):     413.46
(OUTDOOR UNIT)
              Inlet Temperature (°F):     81.90
               Exit Temperature (°F):     97.58
     Condensing Unit Temp Gain (°F):      15.68
          Fan Power Consumption (W):     160.10
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):        0.0
          Sensible Capacity (Btu/h):    28301.6
           Overall Capacity (Btu/h):    27920.1
            Sensible Heat Ratio (-):      1.000
      Overall Power Consumption (W):     2308.3
          NET Cooling EER (Btu/h.W):      12.10
    Evaporator Energy Imbalance (%):       1.29
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):     50.27
               Exit Temperature (°F):     58.63
              Inlet Pressure (psia):     153.17
               Exit Pressure (psia):     143.92
                Pressure Drop (psid):      9.24
                 Exit Superheat (°F):     13.88
           Exit Sat. Temperature (°F):    44.76
         Evaporator Capacity (Btu/h):   28704.3
(CONDENSER)
              Inlet Temperature (°F):    147.72
               Exit Temperature (°F):     90.47
              Inlet Pressure (psia):     336.71
               Exit Pressure (psia):     334.39
                Pressure Drop (psid):      2.32
                Exit Subcooling (°F):      7.75
          Inlet Sat. Temperature (°F):   101.24
          Condenser Capacity (Btu/h):   35694.7
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):     91.39
          Cond Unit Exit Pres (psia):    328.14
      Liq-line Pressure Drop (psid):      11.53
        TXV Upstream Pressure (psia):    316.61
            TXV Pressure Drop (psid):    163.45
               Temperature Drop (°F):      0.61
(COMPRESSOR)
           Suction Temperature (°F):      63.20
         Discharge Temperature (°F):     151.94
             Suction Pressure (psia):    141.55
           Discharge Pressure (psia):    337.27
            Discharge Superheat (°F):     50.85
          Comp Bottom Shell Temp (°F):   108.81
               Mass Flow Rate (lbm/h):   391.94
         Comp Power Consumption (W):     1734.8
            Cond Unit Inlet Temp (°F):    60.86
          Cond Unit Inlet Pres (psia):   142.86
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 13
   FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 11.0
RUNNING CONDITIONS
         Barometric Pressure (inHg):     30.01
   Indoor Dry-Bulb Temperature (°F):     79.99
  Indoor Dew-Point Temperature (°F):     34.22
  Outdoor Dry-Bulb Temperature (°F):     81.85
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):     79.99
   Inlet Dew-Point Temperature (°F):     34.22
     Exit Dry-Bulb Temperature (°F):     51.76
    Exit Dew-Point Temperature (°F):     34.71
        Inlet Relative Humidity (-):     0.191
         Exit Relative Humidity (-):     0.520
     Evaporator Coil Temp Drop (°F):     28.23
               Air Flow Rate (SCFM):     900.1
          Fan Power Consumption (W):    402.36
(OUTDOOR UNIT)
              Inlet Temperature (°F):    81.85
               Exit Temperature (°F):    97.37
     Condensing Unit Temp Gain (°F):     15.51
          Fan Power Consumption (W):    159.95
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):        0.0
         Sensible Capacity (Btu/h):    27655.3
          Overall Capacity (Btu/h):    27305.9
           Sensible Heat Ratio (-):      1.000
      Overall Power Consumption (W):    2293.9
        NET Cooling EER (Btu/h.W):       11.90
    Evaporator Energy Imbalance (%):      2.24
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):    49.54
               Exit Temperature (°F):    57.45
               Inlet Pressure (psia):   151.05
                Exit Pressure (psia):   141.95
                Pressure Drop (psid):     9.10
                 Exit Superheat (°F):    13.52
         Exit Sat. Temperature (°F):     43.93
        Evaporator Capacity (Btu/h):   28342.1
(CONDENSER)
              Inlet Temperature (°F):   147.55
               Exit Temperature (°F):    90.42
               Inlet Pressure (psia):   335.32
                Exit Pressure (psia):   333.00
                Pressure Drop (psid):     2.31
                Exit Subcooling (°F):     7.58
        Inlet Sat. Temperature (°F):    100.94
         Condenser Capacity (Btu/h):   35307.6
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):    91.29
          Cond Unit Exit Pres (psia):   326.91
      Liq-line Pressure Drop (psid):     11.13
       TXV Upstream Pressure (psia):    315.78
           TXV Pressure Drop (psid):    164.73
               Temperature Drop (°F):     0.62
(COMPRESSOR)
            Suction Temperature (°F):    62.17
          Discharge Temperature (°F):   151.87
             Suction Pressure (psia):   139.61
           Discharge Pressure (psia):   335.90
            Discharge Superheat (°F):    51.07
         Comp Bottom Shell Temp (°F):   108.60
              Mass Flow Rate (lbm/h):   387.32
         Comp Power Consumption (W):    1731.6
           Cond Unit Inlet Temp (°F):    59.66
         Cond Unit Inlet Pres (psia):   140.91
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 13
   FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
              FAULT LEVEL [%]: 21.1
RUNNING CONDITIONS
         Barometric Pressure (inHg):     30.01
   Indoor Dry-Bulb Temperature (°F):     80.10
  Indoor Dew-Point Temperature (°F):     33.50
  Outdoor Dry-Bulb Temperature (°F):     81.92
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):     80.10
   Inlet Dew-Point Temperature (°F):     33.50
     Exit Dry-Bulb Temperature (°F):     49.90
    Exit Dew-Point Temperature (°F):     33.94
        Inlet Relative Humidity (-):     0.185
         Exit Relative Humidity (-):     0.540
     Evaporator Coil Temp Drop (°F):     30.20
               Air Flow Rate (SCFM):     802.4
          Fan Power Consumption (W):    383.30
(OUTDOOR UNIT)
              Inlet Temperature (°F):    81.92
               Exit Temperature (°F):    97.01
     Condensing Unit Temp Gain (°F):     15.09
          Fan Power Consumption (W):    159.78
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):        0.0
         Sensible Capacity (Btu/h):    26363.7
          Overall Capacity (Btu/h):    26091.5
           Sensible Heat Ratio (-):      1.000
      Overall Power Consumption (W):    2268.7
        NET Cooling EER (Btu/h.W):       11.50
    Evaporator Energy Imbalance (%):      3.44
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):    47.92
               Exit Temperature (°F):    55.53
               Inlet Pressure (psia):   146.92
                Exit Pressure (psia):   138.00
                Pressure Drop (psid):     8.92
                 Exit Superheat (°F):    13.27
         Exit Sat. Temperature (°F):     42.26
        Evaporator Capacity (Btu/h):   27418.9
(CONDENSER)
              Inlet Temperature (°F):   148.07
               Exit Temperature (°F):    90.32
               Inlet Pressure (psia):   333.44
                Exit Pressure (psia):   331.23
                Pressure Drop (psid):     2.21
                Exit Subcooling (°F):     7.53
        Inlet Sat. Temperature (°F):    100.53
         Condenser Capacity (Btu/h):   34326.2
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):    91.03
          Cond Unit Exit Pres (psia):   325.52
      Liq-line Pressure Drop (psid):     10.45
       TXV Upstream Pressure (psia):    315.07
           TXV Pressure Drop (psid):    168.15
               Temperature Drop (°F):     0.63
(COMPRESSOR)
            Suction Temperature (°F):    60.80
          Discharge Temperature (°F):   152.59
             Suction Pressure (psia):   135.68
           Discharge Pressure (psia):   334.03
            Discharge Superheat (°F):    52.20
         Comp Bottom Shell Temp (°F):   108.84
              Mass Flow Rate (lbm/h):   374.88
         Comp Power Consumption (W):    1725.6
           Cond Unit Inlet Temp (°F):    58.00
         Cond Unit Inlet Pres (psia):   137.00
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 13
 FAULT TYPE: IMPROPER INDOOR AIR FLOW FAULT
            FAULT LEVEL [%]: 30.9
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.88
  Indoor Dry-Bulb Temperature (°F):     80.00
 Indoor Dew-Point Temperature (°F):     33.55
 Outdoor Dry-Bulb Temperature (°F):     81.76
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.00
  Inlet Dew-Point Temperature (°F):     33.55
    Exit Dry-Bulb Temperature (°F):     47.37
   Exit Dew-Point Temperature (°F):     33.93
       Inlet Relative Humidity (-):     0.186
        Exit Relative Humidity (-):     0.593
    Evaporator Coil Temp Drop (°F):     32.63
              Air Flow Rate (SCFM):     701.4
         Fan Power Consumption (W):    363.00
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.76
             Exit Temperature (°F):     96.31
    Condensing Unit Temp Gain (°F):     14.56
         Fan Power Consumption (W):    158.71
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):       0.0
         Sensible Capacity (Btu/h):   24903.8
          Overall Capacity (Btu/h):   24697.4
           Sensible Heat Ratio (-):     1.000
     Overall Power Consumption (W):    2240.0
         NET Cooling EER (Btu/h.W):     11.03
   Evaporator Energy Imbalance (%):      3.96
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     45.73
             Exit Temperature (°F):     52.54
             Inlet Pressure (psia):    141.63
              Exit Pressure (psia):    133.11
              Pressure Drop (psid):      8.53
               Exit Superheat (°F):     12.41
        Exit Sat. Temperature (°F):     40.13
       Evaporator Capacity (Btu/h):   26092.7
(CONDENSER)
            Inlet Temperature (°F):    147.97
             Exit Temperature (°F):     89.89
             Inlet Pressure (psia):    330.23
              Exit Pressure (psia):    328.18
              Pressure Drop (psid):      2.05
              Exit Subcooling (°F):      7.38
       Inlet Sat. Temperature (°F):     99.82
        Condenser Capacity (Btu/h):   32884.7
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     90.59
        Cond Unit Exit Pres (psia):    322.92
     Liq-line Pressure Drop (psid):      9.42
      TXV Upstream Pressure (psia):    313.50
          TXV Pressure Drop (psid):    171.87
             Temperature Drop (°F):      0.60
(COMPRESSOR)
          Suction Temperature (°F):     58.52
        Discharge Temperature (°F):    152.74
           Suction Pressure (psia):    130.77
         Discharge Pressure (psia):    330.84
          Discharge Superheat (°F):     53.06
       Comp Bottom Shell Temp (°F):    108.70
            Mass Flow Rate (lbm/h):    357.66
        Comp Power Consumption (W):    1718.3
         Cond Unit Inlet Temp (°F):     55.24
       Cond Unit Inlet Pres (psia):    132.13
```

D.5 Liquid Line Restriction Fault Tests

Table D.5. List of raw data for liquid line restriction fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	LL	3.7
4	70	50	82	LL	7.0
4	70	50	82	LL	12.5
4	70	50	82	LL	19.0
5	80	50	82	LL	5.3
5	80	50	82	LL	10.4
5	80	50	82	LL	20.2
5	80	50	82	LL	31.9
8	70	50	100	LL	4.4
8	70	50	100	LL	8.8
8	70	50	100	LL	13.3
9	80	50	100	LL	7.1
9	80	50	100	LL	13.3
9	80	50	100	LL	20.0

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: LIQUID LINE RESTRICTION FAULT
               FAULT LEVEL [%]: 3.7
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.33
  Indoor Dry-Bulb Temperature (°F):    69.84
 Indoor Dew-Point Temperature (°F):    50.31
 Outdoor Dry-Bulb Temperature (°F):    81.82
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    69.84
  Inlet Dew-Point Temperature (°F):    50.31
    Exit Dry-Bulb Temperature (°F):    50.52
   Exit Dew-Point Temperature (°F):    47.12
       Inlet Relative Humidity (-):    0.499
        Exit Relative Humidity (-):    0.881
    Evaporator Coil Temp Drop (°F):    19.33
              Air Flow Rate (SCFM):   1031.7
         Fan Power Consumption (W):   424.00
(OUTDOOR UNIT)
             Inlet Temperature (°F):   81.82
              Exit Temperature (°F):   96.75
    Condensing Unit Temp Gain (°F):    14.93
         Fan Power Consumption (W):   159.38
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4268.5
         Sensible Capacity (Btu/h):  21820.3
          Overall Capacity (Btu/h):  26088.7
           Sensible Heat Ratio (-):    0.836
     Overall Power Consumption (W):   2309.9
         NET Cooling EER (Btu/h.W):    11.30
   Evaporator Energy Imbalance (%):     3.45
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    46.13
             Exit Temperature (°F):    55.62
             Inlet Pressure (psia):   147.09
              Exit Pressure (psia):   138.00
              Pressure Drop (psid):     9.09
               Exit Superheat (°F):    13.37
        Exit Sat. Temperature (°F):    42.25
       Evaporator Capacity (Btu/h):  27459.5
(CONDENSER)
            Inlet Temperature (°F):   147.53
             Exit Temperature (°F):    89.74
             Inlet Pressure (psia):   333.13
              Exit Pressure (psia):   330.97
              Pressure Drop (psid):     2.16
              Exit Subcooling (°F):     8.21
       Inlet Sat. Temperature (°F):   100.46
        Condenser Capacity (Btu/h):  34444.5
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    90.24
        Cond Unit Exit Pres (psia):   325.04
     Liq-line Pressure Drop (psid):    16.70
      TXV Upstream Pressure (psia):   308.34
          TXV Pressure Drop (psid):   161.25
             Temperature Drop (°F):     0.95
(COMPRESSOR)
          Suction Temperature (°F):    60.59
        Discharge Temperature (°F):   151.99
           Suction Pressure (psia):   135.68
         Discharge Pressure (psia):   334.02
          Discharge Superheat (°F):    51.60
       Comp Bottom Shell Temp (°F):   108.39
            Mass Flow Rate (lbm/h):   375.44
         Comp Power Consumption (W):  1726.5
          Cond Unit Inlet Temp (°F):   57.76
        Cond Unit Inlet Pres (psia):  137.00
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: LIQUID LINE RESTRICTION FAULT
               FAULT LEVEL [%]: 7.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.24
  Indoor Dry-Bulb Temperature (°F):    69.96
 Indoor Dew-Point Temperature (°F):    50.46
 Outdoor Dry-Bulb Temperature (°F):    81.69
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    69.96
  Inlet Dew-Point Temperature (°F):    50.46
    Exit Dry-Bulb Temperature (°F):    50.77
   Exit Dew-Point Temperature (°F):    47.12
       Inlet Relative Humidity (-):    0.499
        Exit Relative Humidity (-):    0.872
    Evaporator Coil Temp Drop (°F):    19.19
              Air Flow Rate (SCFM):   1027.7
         Fan Power Consumption (W):   425.08
(OUTDOOR UNIT)
             Inlet Temperature (°F):   81.69
              Exit Temperature (°F):   96.65
    Condensing Unit Temp Gain (°F):    14.96
         Fan Power Consumption (W):   159.88
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4472.6
         Sensible Capacity (Btu/h):  21584.3
          Overall Capacity (Btu/h):  26056.9
           Sensible Heat Ratio (-):    0.828
     Overall Power Consumption (W):   2307.5
         NET Cooling EER (Btu/h.W):    11.29
   Evaporator Energy Imbalance (%):     4.17
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    46.26
             Exit Temperature (°F):    55.95
             Inlet Pressure (psia):   147.62
              Exit Pressure (psia):   138.36
              Pressure Drop (psid):     9.26
               Exit Superheat (°F):    13.54
        Exit Sat. Temperature (°F):    42.41
       Evaporator Capacity (Btu/h):  27635.1
(CONDENSER)
            Inlet Temperature (°F):   147.18
             Exit Temperature (°F):    89.80
             Inlet Pressure (psia):   332.36
              Exit Pressure (psia):   330.16
              Pressure Drop (psid):     2.20
              Exit Subcooling (°F):     7.79
       Inlet Sat. Temperature (°F):   100.29
        Condenser Capacity (Btu/h):  34614.2
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):    90.49
        Cond Unit Exit Pres (psia):   324.28
     Liq-line Pressure Drop (psid):    22.12
      TXV Upstream Pressure (psia):   302.16
          TXV Pressure Drop (psid):   154.54
             Temperature Drop (°F):     1.00
(COMPRESSOR)
          Suction Temperature (°F):    60.79
        Discharge Temperature (°F):   151.62
           Suction Pressure (psia):   136.12
         Discharge Pressure (psia):   333.45
          Discharge Superheat (°F):    51.36
       Comp Bottom Shell Temp (°F):   108.30
            Mass Flow Rate (lbm/h):   378.03
         Comp Power Consumption (W):  1722.6
          Cond Unit Inlet Temp (°F):   58.05
        Cond Unit Inlet Pres (psia):  137.41
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 04
  FAULT TYPE: LIQUID LINE RESTRICTION FAULT
             FAULT LEVEL [%]: 12.5
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.25
  Indoor Dry-Bulb Temperature (°F):     69.91
 Indoor Dew-Point Temperature (°F):     50.42
 Outdoor Dry-Bulb Temperature (°F):     81.47
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.91
  Inlet Dew-Point Temperature (°F):     50.42
    Exit Dry-Bulb Temperature (°F):     50.94
   Exit Dew-Point Temperature (°F):     46.53
       Inlet Relative Humidity (-):     0.500
        Exit Relative Humidity (-):     0.848
    Evaporator Coil Temp Drop (°F):     18.97
             Air Flow Rate (SCFM):     1027.2
         Fan Power Consumption (W):    424.23
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.47
             Exit Temperature (°F):     96.52
    Condensing Unit Temp Gain (°F):     15.05
         Fan Power Consumption (W):    159.95
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    5151.7
         Sensible Capacity (Btu/h):   21323.2
          Overall Capacity (Btu/h):   26474.9
           Sensible Heat Ratio (-):     0.805
     Overall Power Consumption (W):    2298.7
         NET Cooling EER (Btu/h.W):     11.52
   Evaporator Energy Imbalance (%):      2.77
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     46.06
             Exit Temperature (°F):     56.32
             Inlet Pressure (psia):    147.32
              Exit Pressure (psia):    138.05
               Pressure Drop (psid):     9.27
               Exit Superheat (°F):     14.05
        Exit Sat. Temperature (°F):     42.27
       Evaporator Capacity (Btu/h):   27663.9
(CONDENSER)
            Inlet Temperature (°F):    147.19
             Exit Temperature (°F):     89.57
             Inlet Pressure (psia):    330.92
              Exit Pressure (psia):    328.67
               Pressure Drop (psid):     2.26
              Exit Subcooling (°F):      7.69
       Inlet Sat. Temperature (°F):     99.97
        Condenser Capacity (Btu/h):   34610.4
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     90.29
        Cond Unit Exit Pres (psia):    322.94
      Liq-line Pressure Drop (psid):    31.34
       TXV Upstream Pressure (psia):   291.59
           TXV Pressure Drop (psid):   144.28
             Temperature Drop (°F):      0.96
(COMPRESSOR)
          Suction Temperature (°F):     61.14
        Discharge Temperature (°F):    151.62
           Suction Pressure (psia):    135.89
         Discharge Pressure (psia):    332.10
          Discharge Superheat (°F):     51.65
       Comp Bottom Shell Temp (°F):    108.33
            Mass Flow Rate (lbm/h):    377.36
        Comp Power Consumption (W):    1714.5
         Cond Unit Inlet Temp (°F):     58.41
       Cond Unit Inlet Pres (psia):    137.16
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 04
  FAULT TYPE: LIQUID LINE RESTRICTION FAULT
             FAULT LEVEL [%]: 19.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.23
  Indoor Dry-Bulb Temperature (°F):     69.81
 Indoor Dew-Point Temperature (°F):     50.53
 Outdoor Dry-Bulb Temperature (°F):     81.49
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.81
  Inlet Dew-Point Temperature (°F):     50.53
    Exit Dry-Bulb Temperature (°F):     51.12
   Exit Dew-Point Temperature (°F):     46.89
       Inlet Relative Humidity (-):     0.503
        Exit Relative Humidity (-):     0.854
    Evaporator Coil Temp Drop (°F):     18.69
             Air Flow Rate (SCFM):     1026.6
         Fan Power Consumption (W):    424.94
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.49
             Exit Temperature (°F):     96.46
    Condensing Unit Temp Gain (°F):     14.97
         Fan Power Consumption (W):    160.09
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4853.7
         Sensible Capacity (Btu/h):   21000.2
          Overall Capacity (Btu/h):   25853.9
           Sensible Heat Ratio (-):     0.812
     Overall Power Consumption (W):    2308.1
         NET Cooling EER (Btu/h.W):     11.20
   Evaporator Energy Imbalance (%):      4.69
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     45.71
             Exit Temperature (°F):     58.06
             Inlet Pressure (psia):    145.89
              Exit Pressure (psia):    136.80
               Pressure Drop (psid):     9.09
               Exit Superheat (°F):     16.33
        Exit Sat. Temperature (°F):     41.74
       Evaporator Capacity (Btu/h):   27570.7
(CONDENSER)
            Inlet Temperature (°F):    149.68
             Exit Temperature (°F):     88.94
             Inlet Pressure (psia):    331.81
              Exit Pressure (psia):    329.69
               Pressure Drop (psid):     2.12
              Exit Subcooling (°F):      8.98
       Inlet Sat. Temperature (°F):    100.17
        Condenser Capacity (Btu/h):   34497.9
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     89.27
        Cond Unit Exit Pres (psia):    324.15
      Liq-line Pressure Drop (psid):    42.08
       TXV Upstream Pressure (psia):   282.07
           TXV Pressure Drop (psid):   136.18
             Temperature Drop (°F):      1.93
(COMPRESSOR)
          Suction Temperature (°F):     62.83
        Discharge Temperature (°F):    154.27
           Suction Pressure (psia):    134.63
         Discharge Pressure (psia):    332.96
          Discharge Superheat (°F):     54.12
       Comp Bottom Shell Temp (°F):    110.78
            Mass Flow Rate (lbm/h):    371.45
        Comp Power Consumption (W):    1723.0
         Cond Unit Inlet Temp (°F):     60.12
       Cond Unit Inlet Pres (psia):    135.90
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: LIQUID LINE RESTRICTION FAULT
                  FAULT LEVEL [%]: 5.3
RUNNING CONDITIONS
          Barometric Pressure (inHg):    30.43
    Indoor Dry-Bulb Temperature (°F):    80.13
   Indoor Dew-Point Temperature (°F):    60.36
   Outdoor Dry-Bulb Temperature (°F):    81.80
AIR SIDE CONDITIONS
(INDOOR UNIT)
     Inlet Dry-Bulb Temperature (°F):    80.13
    Inlet Dew-Point Temperature (°F):    60.36
      Exit Dry-Bulb Temperature (°F):    59.17
     Exit Dew-Point Temperature (°F):    56.18
         Inlet Relative Humidity (-):    0.510
          Exit Relative Humidity (-):    0.898
     Evaporator Coil Temp Drop (°F):     20.96
               Air Flow Rate (SCFM):    1013.8
           Fan Power Consumption (W):   421.74
(OUTDOOR UNIT)
                Inlet Temperature (°F):  81.80
                 Exit Temperature (°F):  99.08
      Condensing Unit Temp Gain (°F):    17.28
           Fan Power Consumption (W):   161.18
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   7527.5
           Sensible Capacity (Btu/h):  23388.1
            Overall Capacity (Btu/h):  30915.6
             Sensible Heat Ratio (-):    0.757
       Overall Power Consumption (W):   2344.8
          NET Cooling EER (Btu/h.W):     13.19
     Evaporator Energy Imbalance (%):     3.03
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
                Inlet Temperature (°F):  54.73
                 Exit Temperature (°F):  65.87
                Inlet Pressure (psia):  169.66
                 Exit Pressure (psia):  159.43
                 Pressure Drop (psid):   10.23
                  Exit Superheat (°F):   14.91
          Exit Sat. Temperature (°F):    50.95
         Evaporator Capacity (Btu/h):  32316.8
(CONDENSER)
                Inlet Temperature (°F): 147.10
                 Exit Temperature (°F):  90.87
                Inlet Pressure (psia):  345.24
                 Exit Pressure (psia):  342.61
                 Pressure Drop (psid):    2.63
                 Exit Subcooling (°F):    8.57
         Inlet Sat. Temperature (°F):   103.08
          Condenser Capacity (Btu/h):  39330.8
(LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F):  92.09
            Cond Unit Exit Pres (psia): 335.01
         Liq-line Pressure Drop (psid):  22.16
          TXV Upstream Pressure (psia): 312.84
              TXV Pressure Drop (psid): 143.18
                 Temperature Drop (°F):   0.70
(COMPRESSOR)
              Suction Temperature (°F):  68.94
            Discharge Temperature (°F): 150.90
              Suction Pressure (psia):  156.96
            Discharge Pressure (psia):  346.48
              Discharge Superheat (°F):  47.82
          Comp Bottom Shell Temp (°F):  109.48
              Mass Flow Rate (lbm/h):   436.71
          Comp Power Consumption (W):   1761.9
             Cond Unit Inlet Temp (°F):  67.26
          Cond Unit Inlet Pres (psia):  158.20
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: LIQUID LINE RESTRICTION FAULT
                  FAULT LEVEL [%]: 10.4
RUNNING CONDITIONS
          Barometric Pressure (inHg):    30.39
    Indoor Dry-Bulb Temperature (°F):    80.03
   Indoor Dew-Point Temperature (°F):    60.50
   Outdoor Dry-Bulb Temperature (°F):    81.80
AIR SIDE CONDITIONS
(INDOOR UNIT)
     Inlet Dry-Bulb Temperature (°F):    80.03
    Inlet Dew-Point Temperature (°F):    60.50
      Exit Dry-Bulb Temperature (°F):    59.67
     Exit Dew-Point Temperature (°F):    56.21
         Inlet Relative Humidity (-):    0.514
          Exit Relative Humidity (-):    0.883
     Evaporator Coil Temp Drop (°F):     20.35
               Air Flow Rate (SCFM):    1012.0
           Fan Power Consumption (W):   418.16
(OUTDOOR UNIT)
                Inlet Temperature (°F):  81.80
                 Exit Temperature (°F):  98.96
      Condensing Unit Temp Gain (°F):    17.16
           Fan Power Consumption (W):   159.95
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   7729.5
           Sensible Capacity (Btu/h):  22667.9
            Overall Capacity (Btu/h):  30397.4
             Sensible Heat Ratio (-):    0.746
       Overall Power Consumption (W):   2336.3
          NET Cooling EER (Btu/h.W):     13.01
     Evaporator Energy Imbalance (%):     4.51
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
                Inlet Temperature (°F):  54.50
                 Exit Temperature (°F):  66.84
                Inlet Pressure (psia):  168.49
                 Exit Pressure (psia):  158.15
                 Pressure Drop (psid):   10.35
                  Exit Superheat (°F):   16.39
          Exit Sat. Temperature (°F):    50.46
         Evaporator Capacity (Btu/h):  32272.1
(CONDENSER)
                Inlet Temperature (°F): 148.28
                 Exit Temperature (°F):  90.86
                Inlet Pressure (psia):  344.47
                 Exit Pressure (psia):  341.85
                 Pressure Drop (psid):    2.62
                 Exit Subcooling (°F):    8.53
         Inlet Sat. Temperature (°F):   102.92
          Condenser Capacity (Btu/h):  39244.3
(LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F):  92.01
            Cond Unit Exit Pres (psia): 334.44
         Liq-line Pressure Drop (psid):  29.95
          TXV Upstream Pressure (psia): 304.48
              TXV Pressure Drop (psid): 135.99
                 Temperature Drop (°F):   0.66
(COMPRESSOR)
              Suction Temperature (°F):  69.90
            Discharge Temperature (°F): 152.05
              Suction Pressure (psia):  155.75
            Discharge Pressure (psia):  345.60
              Discharge Superheat (°F):  49.16
          Comp Bottom Shell Temp (°F):  110.56
              Mass Flow Rate (lbm/h):   433.78
          Comp Power Consumption (W):   1758.2
             Cond Unit Inlet Temp (°F):  68.25
          Cond Unit Inlet Pres (psia):  156.96
```

```
               HEAT PUMP FAULT TEST SUMMARY

              INDOOR/OUTDOOR CONDITION #: 05
        FAULT TYPE: LIQUID LINE RESTRICTION FAULT
                  FAULT LEVEL [%]: 20.2
RUNNING CONDITIONS
            Barometric Pressure (inHg):     30.35
      Indoor Dry-Bulb Temperature (°F):     79.96
     Indoor Dew-Point Temperature (°F):     60.66
     Outdoor Dry-Bulb Temperature (°F):     82.06
AIR SIDE CONDITIONS
 (INDOOR UNIT)
       Inlet Dry-Bulb Temperature (°F):     79.96
      Inlet Dew-Point Temperature (°F):     60.66
        Exit Dry-Bulb Temperature (°F):     60.35
       Exit Dew-Point Temperature (°F):     56.54
           Inlet Relative Humidity (-):     0.518
            Exit Relative Humidity (-):     0.872
        Evaporator Coil Temp Drop (°F):     19.62
                  Air Flow Rate (SCFM):    1008.8
            Fan Power Consumption (W):     418.33
 (OUTDOOR UNIT)
                 Inlet Temperature (°F):    82.06
                  Exit Temperature (°F):    98.24
       Condensing Unit Temp Gain (°F):      16.17
            Fan Power Consumption (W):     159.45
 (OVERALL PERFORMANCE)
              Latent Capacity (Btu/h):     7477.4
            Sensible Capacity (Btu/h):    21783.3
             Overall Capacity (Btu/h):    29260.6
              Sensible Heat Ratio (-):      0.744
        Overall Power Consumption (W):     2344.8
            NET Cooling EER (Btu/h.W):      12.48
     Evaporator Energy Imbalance (%):        2.73
REFRIGERANT SIDE CONDITIONS
 (EVAPORATOR)
                Inlet Temperature (°F):     51.13
                 Exit Temperature (°F):     70.12
                 Inlet Pressure (psia):    157.98
                  Exit Pressure (psia):    148.60
                   Pressure Drop (psid):     9.38
                    Exit Superheat (°F):    23.45
           Exit Sat. Temperature (°F):      46.68
          Evaporator Capacity (Btu/h):    30511.2
 (CONDENSER)
                Inlet Temperature (°F):    155.46
                 Exit Temperature (°F):     89.64
                 Inlet Pressure (psia):    342.89
                  Exit Pressure (psia):    340.65
                   Pressure Drop (psid):     2.24
                  Exit Subcooling (°F):     10.72
          Inlet Sat. Temperature (°F):     102.58
           Condenser Capacity (Btu/h):    37348.4
 (LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F):     89.83
            Cond Unit Exit Pres (psia):    334.52
       Liq-line Pressure Drop (psid):       44.81
        TXV Upstream Pressure (psia):      289.71
            TXV Pressure Drop (psid):      131.73
                 Temperature Drop (°F):      0.48
 (COMPRESSOR)
              Suction Temperature (°F):     73.48
            Discharge Temperature (°F):    159.83
               Suction Pressure (psia):    146.40
             Discharge Pressure (psia):    343.76
              Discharge Superheat (°F):     57.33
           Comp Bottom Shell Temp (°F):    116.77
                 Mass Flow Rate (lbm/h):   398.43
          Comp Power Consumption (W):      1767.0
             Cond Unit Inlet Temp (°F):     71.47
           Cond Unit Inlet Pres (psia):    147.57
```

```
               HEAT PUMP FAULT TEST SUMMARY

              INDOOR/OUTDOOR CONDITION #: 05
        FAULT TYPE: LIQUID LINE RESTRICTION FAULT
                  FAULT LEVEL [%]: 31.9
RUNNING CONDITIONS
            Barometric Pressure (inHg):     30.33
      Indoor Dry-Bulb Temperature (°F):     79.93
     Indoor Dew-Point Temperature (°F):     60.65
     Outdoor Dry-Bulb Temperature (°F):     82.10
AIR SIDE CONDITIONS
 (INDOOR UNIT)
       Inlet Dry-Bulb Temperature (°F):     79.93
      Inlet Dew-Point Temperature (°F):     60.65
        Exit Dry-Bulb Temperature (°F):     62.48
       Exit Dew-Point Temperature (°F):     58.21
           Inlet Relative Humidity (-):     0.518
            Exit Relative Humidity (-):     0.859
        Evaporator Coil Temp Drop (°F):     17.45
                  Air Flow Rate (SCFM):    1005.9
            Fan Power Consumption (W):     419.60
 (OUTDOOR UNIT)
                 Inlet Temperature (°F):    82.10
                  Exit Temperature (°F):    95.71
       Condensing Unit Temp Gain (°F):      13.62
            Fan Power Consumption (W):     160.32
 (OVERALL PERFORMANCE)
              Latent Capacity (Btu/h):     4541.8
            Sensible Capacity (Btu/h):    19333.4
             Overall Capacity (Btu/h):    23875.2
              Sensible Heat Ratio (-):      0.810
        Overall Power Consumption (W):     2321.7
            NET Cooling EER (Btu/h.W):      10.28
     Evaporator Energy Imbalance (%):       -2.53
REFRIGERANT SIDE CONDITIONS
 (EVAPORATOR)
                Inlet Temperature (°F):     41.30
                 Exit Temperature (°F):     71.61
                 Inlet Pressure (psia):    132.00
                  Exit Pressure (psia):    124.46
                   Pressure Drop (psid):     7.54
                    Exit Superheat (°F):    35.39
           Exit Sat. Temperature (°F):      36.22
          Evaporator Capacity (Btu/h):    23696.0
 (CONDENSER)
                Inlet Temperature (°F):    168.00
                 Exit Temperature (°F):     88.02
                 Inlet Pressure (psia):    331.54
                  Exit Pressure (psia):    329.96
                   Pressure Drop (psid):     1.58
                  Exit Subcooling (°F):     11.25
          Inlet Sat. Temperature (°F):     100.11
           Condenser Capacity (Btu/h):    30039.5
 (LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F):     87.49
            Cond Unit Exit Pres (psia):    326.31
       Liq-line Pressure Drop (psid):       62.45
        TXV Upstream Pressure (psia):      263.87
            TXV Pressure Drop (psid):      131.87
                 Temperature Drop (°F):      4.83
 (COMPRESSOR)
              Suction Temperature (°F):     76.13
            Discharge Temperature (°F):    174.64
               Suction Pressure (psia):    122.37
             Discharge Pressure (psia):    332.47
              Discharge Superheat (°F):     74.60
           Comp Bottom Shell Temp (°F):    125.89
                 Mass Flow Rate (lbm/h):   302.35
          Comp Power Consumption (W):      1741.7
             Cond Unit Inlet Temp (°F):     73.13
           Cond Unit Inlet Pres (psia):    123.62
```

```
                HEAT PUMP FAULT TEST SUMMARY

              INDOOR/OUTDOOR CONDITION #: 08
        FAULT TYPE: LIQUID LINE RESTRICTION FAULT
                    FAULT LEVEL [%]: 4.4
RUNNING CONDITIONS
          Barometric Pressure (inHg):    29.70
   Indoor Dry-Bulb Temperature (°F):     70.21
  Indoor Dew-Point Temperature (°F):     50.35
  Outdoor Dry-Bulb Temperature (°F):    100.02
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):     70.21
   Inlet Dew-Point Temperature (°F):     50.35
     Exit Dry-Bulb Temperature (°F):     52.06
    Exit Dew-Point Temperature (°F):     47.84
        Inlet Relative Humidity (-):     0.493
         Exit Relative Humidity (-):     0.855
      Evaporator Coil Temp Drop (°F):    18.15
                Air Flow Rate (SCFM):   1005.6
          Fan Power Consumption (W):    416.67
(OUTDOOR UNIT)
               Inlet Temperature (°F):  100.02
                Exit Temperature (°F):  115.09
      Condensing Unit Temp Gain (°F):    15.07
          Fan Power Consumption (W):    154.18
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   3384.8
           Sensible Capacity (Btu/h):  19980.4
            Overall Capacity (Btu/h):  23365.2
              Sensible Heat Ratio (-):   0.855
       Overall Power Consumption (W):   2785.2
          NET Cooling EER (Btu/h.W):      8.39
    Evaporator Energy Imbalance (%):      2.00
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):   47.61
                Exit Temperature (°F):   56.61
                Inlet Pressure (psia):  152.66
                 Exit Pressure (psia):  142.13
                 Pressure Drop (psid):   10.53
                  Exit Superheat (°F):   12.61
          Exit Sat. Temperature (°F):    44.00
         Evaporator Capacity (Btu/h):  24267.9
(CONDENSER)
               Inlet Temperature (°F):  177.10
                Exit Temperature (°F):  109.53
                Inlet Pressure (psia):  421.33
                 Exit Pressure (psia):  419.43
                 Pressure Drop (psid):    1.90
                  Exit Subcooling (°F):   6.97
         Inlet Sat. Temperature (°F):   118.11
          Condenser Capacity (Btu/h):  33103.3
(LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F):  109.56
            Cond Unit Exit Pres (psia):  413.86
        Liq-line Pressure Drop (psid):    22.22
         TXV Upstream Pressure (psia):   391.64
             TXV Pressure Drop (psid):   238.98
                 Temperature Drop (°F):    1.41
(COMPRESSOR)
             Suction Temperature (°F):    63.58
           Discharge Temperature (°F):   182.55
              Suction Pressure (psia):   139.96
            Discharge Pressure (psia):   422.70
              Discharge Superheat (°F):   64.42
         Comp Bottom Shell Temp (°F):    127.07
              Mass Flow Rate (lbm/h):    374.64
         Comp Power Consumption (W):     2214.4
            Cond Unit Inlet Temp (°F):    59.30
          Cond Unit Inlet Pres (psia):   141.17
```

```
                HEAT PUMP FAULT TEST SUMMARY

              INDOOR/OUTDOOR CONDITION #: 08
        FAULT TYPE: LIQUID LINE RESTRICTION FAULT
                    FAULT LEVEL [%]: 8.8
RUNNING CONDITIONS
          Barometric Pressure (inHg):    29.71
   Indoor Dry-Bulb Temperature (°F):     70.17
  Indoor Dew-Point Temperature (°F):     50.41
  Outdoor Dry-Bulb Temperature (°F):    100.09
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):     70.17
   Inlet Dew-Point Temperature (°F):     50.41
     Exit Dry-Bulb Temperature (°F):     51.95
    Exit Dew-Point Temperature (°F):     48.08
        Inlet Relative Humidity (-):     0.495
         Exit Relative Humidity (-):     0.866
      Evaporator Coil Temp Drop (°F):    18.22
                Air Flow Rate (SCFM):   1010.3
          Fan Power Consumption (W):    417.00
(OUTDOOR UNIT)
               Inlet Temperature (°F):  100.09
                Exit Temperature (°F):  115.15
      Condensing Unit Temp Gain (°F):    15.07
          Fan Power Consumption (W):    154.48
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   3163.7
           Sensible Capacity (Btu/h):  20156.4
            Overall Capacity (Btu/h):  23320.2
              Sensible Heat Ratio (-):   0.864
       Overall Power Consumption (W):   2790.7
          NET Cooling EER (Btu/h.W):      8.36
    Evaporator Energy Imbalance (%):      2.84
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):   48.02
                Exit Temperature (°F):   57.00
                Inlet Pressure (psia):  153.09
                 Exit Pressure (psia):  142.51
                 Pressure Drop (psid):   10.58
                  Exit Superheat (°F):   12.84
          Exit Sat. Temperature (°F):    44.16
         Evaporator Capacity (Btu/h):  24431.2
(CONDENSER)
               Inlet Temperature (°F):  177.05
                Exit Temperature (°F):  109.84
                Inlet Pressure (psia):  421.62
                 Exit Pressure (psia):  419.72
                 Pressure Drop (psid):    1.91
                  Exit Subcooling (°F):   6.71
         Inlet Sat. Temperature (°F):   118.16
          Condenser Capacity (Btu/h):  33281.2
(LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F):  109.86
            Cond Unit Exit Pres (psia):  414.02
        Liq-line Pressure Drop (psid):    33.14
         TXV Upstream Pressure (psia):   380.88
             TXV Pressure Drop (psid):   227.80
                 Temperature Drop (°F):    1.54
(COMPRESSOR)
             Suction Temperature (°F):    63.91
           Discharge Temperature (°F):   182.47
              Suction Pressure (psia):   140.34
            Discharge Pressure (psia):   422.82
              Discharge Superheat (°F):   64.31
         Comp Bottom Shell Temp (°F):    126.95
              Mass Flow Rate (lbm/h):    377.41
         Comp Power Consumption (W):     2219.2
            Cond Unit Inlet Temp (°F):    59.69
          Cond Unit Inlet Pres (psia):   141.58
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 08
  FAULT TYPE: LIQUID LINE RESTRICTION FAULT
            FAULT LEVEL [%]: 13.3
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.71
  Indoor Dry-Bulb Temperature (°F):     70.24
 Indoor Dew-Point Temperature (°F):     50.45
 Outdoor Dry-Bulb Temperature (°F):    100.09
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.24
  Inlet Dew-Point Temperature (°F):     50.45
    Exit Dry-Bulb Temperature (°F):     51.97
   Exit Dew-Point Temperature (°F):     47.92
       Inlet Relative Humidity (-):     0.495
        Exit Relative Humidity (-):     0.860
    Evaporator Coil Temp Drop (°F):     18.27
           Air Flow Rate (SCFM):      1011.1
       Fan Power Consumption (W):     416.91
(OUTDOOR UNIT)
             Inlet Temperature (°F):    100.09
              Exit Temperature (°F):    115.17
    Condensing Unit Temp Gain (°F):     15.09
       Fan Power Consumption (W):     154.33
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):     3443.1
        Sensible Capacity (Btu/h):    20228.9
         Overall Capacity (Btu/h):    23672.0
          Sensible Heat Ratio (-):      0.855
   Overall Power Consumption (W):     2794.6
      NET Cooling EER (Btu/h.W):       8.47
   Evaporator Energy Imbalance (%):      1.28
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     48.15
              Exit Temperature (°F):     57.35
             Inlet Pressure (psia):    153.04
              Exit Pressure (psia):    142.53
             Pressure Drop (psid):     10.52
               Exit Superheat (°F):     13.18
        Exit Sat. Temperature (°F):     44.17
       Evaporator Capacity (Btu/h):   24400.5
(CONDENSER)
             Inlet Temperature (°F):    177.51
              Exit Temperature (°F):    109.67
             Inlet Pressure (psia):    422.30
              Exit Pressure (psia):    420.41
             Pressure Drop (psid):      1.90
              Exit Subcooling (°F):      7.16
       Inlet Sat. Temperature (°F):    118.29
        Condenser Capacity (Btu/h):   33224.3
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    109.54
        Cond Unit Exit Pres (psia):    414.77
     Liq-line Pressure Drop (psid):     44.12
      TXV Upstream Pressure (psia):    370.64
         TXV Pressure Drop (psid):    217.60
              Temperature Drop (°F):      1.90
(COMPRESSOR)
          Suction Temperature (°F):     64.23
        Discharge Temperature (°F):    182.95
           Suction Pressure (psia):    140.36
         Discharge Pressure (psia):    423.50
          Discharge Superheat (°F):     64.67
       Comp Bottom Shell Temp (°F):    127.34
          Mass Flow Rate (lbm/h):    375.62
      Comp Power Consumption (W):     2223.4
         Cond Unit Inlet Temp (°F):     60.03
       Cond Unit Inlet Pres (psia):    141.59
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 09
  FAULT TYPE: LIQUID LINE RESTRICTION FAULT
            FAULT LEVEL [%]: 7.1
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.44
  Indoor Dry-Bulb Temperature (°F):     80.03
 Indoor Dew-Point Temperature (°F):     60.59
 Outdoor Dry-Bulb Temperature (°F):     99.84
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.03
  Inlet Dew-Point Temperature (°F):     60.59
    Exit Dry-Bulb Temperature (°F):     60.83
   Exit Dew-Point Temperature (°F):     57.33
       Inlet Relative Humidity (-):     0.515
        Exit Relative Humidity (-):     0.882
    Evaporator Coil Temp Drop (°F):     19.20
           Air Flow Rate (SCFM):      1010.0
       Fan Power Consumption (W):     421.72
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.84
              Exit Temperature (°F):    116.65
    Condensing Unit Temp Gain (°F):     16.81
       Fan Power Consumption (W):     157.83
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):     5967.9
        Sensible Capacity (Btu/h):    21346.4
         Overall Capacity (Btu/h):    27314.3
          Sensible Heat Ratio (-):      0.782
   Overall Power Consumption (W):     2821.4
      NET Cooling EER (Btu/h.W):       9.68
   Evaporator Energy Imbalance (%):      3.33
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     56.06
              Exit Temperature (°F):     66.95
             Inlet Pressure (psia):    174.74
              Exit Pressure (psia):    162.97
             Pressure Drop (psid):     11.78
               Exit Superheat (°F):     14.64
        Exit Sat. Temperature (°F):     52.30
       Evaporator Capacity (Btu/h):   28691.9
(CONDENSER)
             Inlet Temperature (°F):    174.80
              Exit Temperature (°F):    109.74
             Inlet Pressure (psia):    432.19
              Exit Pressure (psia):    429.95
             Pressure Drop (psid):      2.24
              Exit Subcooling (°F):      7.46
       Inlet Sat. Temperature (°F):    120.08
        Condenser Capacity (Btu/h):   37570.0
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    110.59
        Cond Unit Exit Pres (psia):    422.06
     Liq-line Pressure Drop (psid):     31.93
      TXV Upstream Pressure (psia):    390.12
         TXV Pressure Drop (psid):    215.38
              Temperature Drop (°F):      1.09
(COMPRESSOR)
          Suction Temperature (°F):     71.84
        Discharge Temperature (°F):    179.07
           Suction Pressure (psia):    160.68
         Discharge Pressure (psia):    432.78
          Discharge Superheat (°F):     59.10
       Comp Bottom Shell Temp (°F):    125.29
          Mass Flow Rate (lbm/h):    434.90
      Comp Power Consumption (W):     2241.8
         Cond Unit Inlet Temp (°F):     68.93
       Cond Unit Inlet Pres (psia):    161.85
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 09
   FAULT TYPE: LIQUID LINE RESTRICTION FAULT
             FAULT LEVEL [%]: 13.3
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.03
   Indoor Dry-Bulb Temperature (°F):    79.82
  Indoor Dew-Point Temperature (°F):    60.71
  Outdoor Dry-Bulb Temperature (°F):    99.93
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    79.82
   Inlet Dew-Point Temperature (°F):    60.71
     Exit Dry-Bulb Temperature (°F):    60.87
    Exit Dew-Point Temperature (°F):    57.20
        Inlet Relative Humidity (-):    0.521
         Exit Relative Humidity (-):    0.877
     Evaporator Coil Temp Drop (°F):    18.95
               Air Flow Rate (SCFM):    997.9
          Fan Power Consumption (W):   417.67
(OUTDOOR UNIT)
               Inlet Temperature (°F):   99.93
                Exit Temperature (°F):  116.87
     Condensing Unit Temp Gain (°F):    16.94
          Fan Power Consumption (W):   156.06
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   6452.9
           Sensible Capacity (Btu/h):  20822.8
            Overall Capacity (Btu/h):  27275.7
             Sensible Heat Ratio (-):    0.763
      Overall Power Consumption (W):    2826.4
          NET Cooling EER (Btu/h.W):      9.65
    Evaporator Energy Imbalance (%):      3.36
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):    55.57
               Exit Temperature (°F):    67.86
               Inlet Pressure (psia):   174.41
                Exit Pressure (psia):   162.47
                Pressure Drop (psid):    11.94
                 Exit Superheat (°F):    15.75
         Exit Sat. Temperature (°F):     52.12
       Evaporator Capacity (Btu/h):    28655.6
(CONDENSER)
              Inlet Temperature (°F):   176.32
               Exit Temperature (°F):   109.97
               Inlet Pressure (psia):   433.40
                Exit Pressure (psia):   431.22
                Pressure Drop (psid):     2.18
                Exit Subcooling (°F):     7.53
        Inlet Sat. Temperature (°F):    120.29
         Condenser Capacity (Btu/h):   37538.5
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):   110.84
          Cond Unit Exit Pres (psia):   423.82
      Liq-line Pressure Drop (psid):     46.34
     TXV Upstream Pressure (psia):      377.48
          TXV Pressure Drop (psid):     203.07
              Temperature Drop (°F):      1.26
(COMPRESSOR)
            Suction Temperature (°F):    72.74
          Discharge Temperature (°F):   180.55
             Suction Pressure (psia):   160.23
           Discharge Pressure (psia):   434.42
            Discharge Superheat (°F):    60.29
       Comp Bottom Shell Temp (°F):     126.84
              Mass Flow Rate (lbm/h):   433.09
         Comp Power Consumption (W):    2252.7
           Cond Unit Inlet Temp (°F):    69.86
        Cond Unit Inlet Pres (psia):    161.32
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 09
   FAULT TYPE: LIQUID LINE RESTRICTION FAULT
             FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.04
   Indoor Dry-Bulb Temperature (°F):    79.92
  Indoor Dew-Point Temperature (°F):    60.79
  Outdoor Dry-Bulb Temperature (°F):   100.01
AIR SIDE CONDITIONS
(INDOOR UNIT)
    Inlet Dry-Bulb Temperature (°F):    79.92
   Inlet Dew-Point Temperature (°F):    60.79
     Exit Dry-Bulb Temperature (°F):    61.18
    Exit Dew-Point Temperature (°F):    57.44
        Inlet Relative Humidity (-):    0.521
         Exit Relative Humidity (-):    0.875
     Evaporator Coil Temp Drop (°F):    18.74
               Air Flow Rate (SCFM):    996.6
          Fan Power Consumption (W):   415.15
(OUTDOOR UNIT)
               Inlet Temperature (°F):  100.01
                Exit Temperature (°F):  116.57
     Condensing Unit Temp Gain (°F):    16.56
          Fan Power Consumption (W):   155.46
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   6166.6
           Sensible Capacity (Btu/h):  20571.1
            Overall Capacity (Btu/h):  26737.7
             Sensible Heat Ratio (-):    0.769
      Overall Power Consumption (W):    2841.6
          NET Cooling EER (Btu/h.W):      9.41
    Evaporator Energy Imbalance (%):      4.30
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):    53.72
               Exit Temperature (°F):    70.76
               Inlet Pressure (psia):   168.12
                Exit Pressure (psia):   157.01
                Pressure Drop (psid):    11.11
                 Exit Superheat (°F):    20.74
         Exit Sat. Temperature (°F):     50.02
       Evaporator Capacity (Btu/h):    28373.9
(CONDENSER)
              Inlet Temperature (°F):   182.67
               Exit Temperature (°F):   108.79
               Inlet Pressure (psia):   433.62
                Exit Pressure (psia):   431.64
                Pressure Drop (psid):     1.98
                Exit Subcooling (°F):     9.71
        Inlet Sat. Temperature (°F):    120.33
         Condenser Capacity (Btu/h):   37334.5
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):   108.90
          Cond Unit Exit Pres (psia):   425.19
      Liq-line Pressure Drop (psid):     62.14
     TXV Upstream Pressure (psia):      363.05
          TXV Pressure Drop (psid):     194.93
              Temperature Drop (°F):      2.71
(COMPRESSOR)
            Suction Temperature (°F):    75.92
          Discharge Temperature (°F):   187.42
             Suction Pressure (psia):   154.83
           Discharge Pressure (psia):   434.67
            Discharge Superheat (°F):    67.12
       Comp Bottom Shell Temp (°F):     133.55
              Mass Flow Rate (lbm/h):   416.41
         Comp Power Consumption (W):    2271.0
           Cond Unit Inlet Temp (°F):    72.72
        Cond Unit Inlet Pres (psia):    155.95
```

D.6 Refrigerant Undercharge Fault Tests

Table D.6. List of raw data for refrigerant undercharge fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	UC	10.0
4	70	50	82	UC	20.0
4	70	50	82	UC	30.0
5	80	50	82	UC	10.0
5	80	50	82	UC	20.0
5	80	50	82	UC	30.0
8	70	50	100	UC	10.0
8	70	50	100	UC	20.0
8	70	50	100	UC	30.0
9	80	50	100	UC	10.0
9	80	50	100	UC	20.0
9	80	50	100	UC	30.0

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
             FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.31
  Indoor Dry-Bulb Temperature (°F):     69.98
 Indoor Dew-Point Temperature (°F):     50.28
 Outdoor Dry-Bulb Temperature (°F):     81.67
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.98
  Inlet Dew-Point Temperature (°F):     50.28
    Exit Dry-Bulb Temperature (°F):     51.29
   Exit Dew-Point Temperature (°F):     47.41
       Inlet Relative Humidity (-):     0.496
        Exit Relative Humidity (-):     0.865
    Evaporator Coil Temp Drop (°F):     18.69
              Air Flow Rate (SCFM):    1028.0
         Fan Power Consumption (W):    424.78
(OUTDOOR UNIT)
             Inlet Temperature (°F):     81.67
              Exit Temperature (°F):     96.28
    Condensing Unit Temp Gain (°F):     14.61
         Fan Power Consumption (W):    159.71
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3843.0
         Sensible Capacity (Btu/h):   21026.8
          Overall Capacity (Btu/h):   24869.8
           Sensible Heat Ratio (-):     0.845
     Overall Power Consumption (W):    2291.7
        NET Cooling EER (Btu/h.W):     10.85
   Evaporator Energy Imbalance (%):      5.62
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     46.08
              Exit Temperature (°F):     56.90
              Inlet Pressure (psia):    149.07
               Exit Pressure (psia):    138.77
               Pressure Drop (psid):     10.30
                Exit Superheat (°F):     14.32
        Exit Sat. Temperature (°F):     42.58
       Evaporator Capacity (Btu/h):   26800.8
(CONDENSER)
             Inlet Temperature (°F):    146.64
              Exit Temperature (°F):     92.80
              Inlet Pressure (psia):    328.67
               Exit Pressure (psia):    326.17
               Pressure Drop (psid):      2.49
               Exit Subcooling (°F):      2.28
       Inlet Sat. Temperature (°F):     99.47
        Condenser Capacity (Btu/h):   33638.7
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     94.99
        Cond Unit Exit Pres (psia):    319.83
     Liq-line Pressure Drop (psid):     10.68
      TXV Upstream Pressure (psia):    309.15
          TXV Pressure Drop (psid):    160.09
             Temperature Drop (°F):      1.57
(COMPRESSOR)
          Suction Temperature (°F):     61.55
        Discharge Temperature (°F):    150.77
           Suction Pressure (psia):    136.59
         Discharge Pressure (psia):    329.62
          Discharge Superheat (°F):     51.35
       Comp Bottom Shell Temp (°F):    108.31
             Mass Flow Rate (lbm/h):    375.69
        Comp Power Consumption (W):    1707.2
         Cond Unit Inlet Temp (°F):     58.83
       Cond Unit Inlet Pres (psia):    137.86
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
             FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.31
  Indoor Dry-Bulb Temperature (°F):     69.98
 Indoor Dew-Point Temperature (°F):     50.87
 Outdoor Dry-Bulb Temperature (°F):     81.65
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.98
  Inlet Dew-Point Temperature (°F):     50.87
    Exit Dry-Bulb Temperature (°F):     51.80
   Exit Dew-Point Temperature (°F):     47.66
       Inlet Relative Humidity (-):     0.507
        Exit Relative Humidity (-):     0.857
    Evaporator Coil Temp Drop (°F):     18.18
              Air Flow Rate (SCFM):    1027.1
         Fan Power Consumption (W):    422.39
(OUTDOOR UNIT)
             Inlet Temperature (°F):     81.65
              Exit Temperature (°F):     95.90
    Condensing Unit Temp Gain (°F):     14.25
         Fan Power Consumption (W):    158.83
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    4351.0
         Sensible Capacity (Btu/h):   20438.8
          Overall Capacity (Btu/h):   24789.8
           Sensible Heat Ratio (-):     0.824
     Overall Power Consumption (W):    2279.9
        NET Cooling EER (Btu/h.W):     10.87
   Evaporator Energy Imbalance (%):      4.97
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     44.98
              Exit Temperature (°F):     60.57
              Inlet Pressure (psia):    145.63
               Exit Pressure (psia):    135.67
               Pressure Drop (psid):      9.96
                Exit Superheat (°F):     19.33
        Exit Sat. Temperature (°F):     41.25
       Evaporator Capacity (Btu/h):   26530.7
(CONDENSER)
             Inlet Temperature (°F):    150.71
              Exit Temperature (°F):     93.65
              Inlet Pressure (psia):    325.56
               Exit Pressure (psia):    323.14
               Pressure Drop (psid):      2.42
               Exit Subcooling (°F):      1.52
       Inlet Sat. Temperature (°F):     98.78
        Condenser Capacity (Btu/h):   33325.3
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     95.06
        Cond Unit Exit Pres (psia):    316.76
     Liq-line Pressure Drop (psid):     11.37
      TXV Upstream Pressure (psia):    305.39
          TXV Pressure Drop (psid):    159.76
             Temperature Drop (°F):      2.25
(COMPRESSOR)
          Suction Temperature (°F):     65.21
        Discharge Temperature (°F):    155.31
           Suction Pressure (psia):    133.62
         Discharge Pressure (psia):    326.84
          Discharge Superheat (°F):     56.51
       Comp Bottom Shell Temp (°F):    113.23
             Mass Flow Rate (lbm/h):    366.43
        Comp Power Consumption (W):    1698.7
         Cond Unit Inlet Temp (°F):     62.65
       Cond Unit Inlet Pres (psia):    134.85
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 04
  FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
            FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.66
  Indoor Dry-Bulb Temperature (°F):     70.05
 Indoor Dew-Point Temperature (°F):     50.74
 Outdoor Dry-Bulb Temperature (°F):     81.63
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.05
  Inlet Dew-Point Temperature (°F):     50.74
    Exit Dry-Bulb Temperature (°F):     52.46
   Exit Dew-Point Temperature (°F):     47.85
       Inlet Relative Humidity (-):     0.503
        Exit Relative Humidity (-):     0.842
    Evaporator Coil Temp Drop (°F):     17.59
             Air Flow Rate (SCFM):     1008.9
        Fan Power Consumption (W):     420.59
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.63
             Exit Temperature (°F):     95.05
    Condensing Unit Temp Gain (°F):     13.41
        Fan Power Consumption (W):     158.24
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3930.0
         Sensible Capacity (Btu/h):   19426.6
          Overall Capacity (Btu/h):   23356.7
           Sensible Heat Ratio (-):     0.832
    Overall Power Consumption (W):     2256.6
         NET Cooling EER (Btu/h.W):     10.35
   Evaporator Energy Imbalance (%):       N/A
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     41.70
             Exit Temperature (°F):     61.01
             Inlet Pressure (psia):    136.16
              Exit Pressure (psia):    126.83
              Pressure Drop (psid):      9.33
               Exit Superheat (°F):     23.70
        Exit Sat. Temperature (°F):     37.31
       Evaporator Capacity (Btu/h):       N/A
(CONDENSER)
            Inlet Temperature (°F):    155.24
             Exit Temperature (°F):     93.80
             Inlet Pressure (psia):    319.93
              Exit Pressure (psia):    317.69
              Pressure Drop (psid):      2.23
              Exit Subcooling (°F):      1.13
       Inlet Sat. Temperature (°F):     97.51
        Condenser Capacity (Btu/h):       N/A
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     94.24
        Cond Unit Exit Pres (psia):    311.50
     Liq-line Pressure Drop (psid):     11.30
      TXV Upstream Pressure (psia):    300.20
          TXV Pressure Drop (psid):    164.05
             Temperature Drop (°F):      2.48
(COMPRESSOR)
         Suction Temperature (°F):     66.13
       Discharge Temperature (°F):    160.71
           Suction Pressure (psia):    124.75
         Discharge Pressure (psia):    321.04
          Discharge Superheat (°F):     63.22
       Comp Bottom Shell Temp (°F):    117.41
            Mass Flow Rate (lbm/h):    127.80
        Comp Power Consumption (W):    1677.8
          Cond Unit Inlet Temp (°F):     63.08
       Cond Unit Inlet Pres (psia):    126.03
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 05
  FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
            FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.26
  Indoor Dry-Bulb Temperature (°F):     79.97
 Indoor Dew-Point Temperature (°F):     60.19
 Outdoor Dry-Bulb Temperature (°F):     81.71
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.97
  Inlet Dew-Point Temperature (°F):     60.19
    Exit Dry-Bulb Temperature (°F):     60.15
   Exit Dew-Point Temperature (°F):     56.44
       Inlet Relative Humidity (-):     0.509
        Exit Relative Humidity (-):     0.875
    Evaporator Coil Temp Drop (°F):     19.82
             Air Flow Rate (SCFM):     1004.8
        Fan Power Consumption (W):     416.88
(OUTDOOR UNIT)
            Inlet Temperature (°F):     81.71
             Exit Temperature (°F):     98.16
    Condensing Unit Temp Gain (°F):     16.45
        Fan Power Consumption (W):     158.63
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    6739.9
         Sensible Capacity (Btu/h):   21920.5
          Overall Capacity (Btu/h):   28660.4
           Sensible Heat Ratio (-):     0.765
    Overall Power Consumption (W):     2311.7
         NET Cooling EER (Btu/h.W):     12.40
   Evaporator Energy Imbalance (%):      5.92
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     53.23
             Exit Temperature (°F):     69.91
             Inlet Pressure (psia):    166.21
              Exit Pressure (psia):    155.32
              Pressure Drop (psid):     10.88
               Exit Superheat (°F):     20.55
        Exit Sat. Temperature (°F):     49.36
       Evaporator Capacity (Btu/h):   30905.9
(CONDENSER)
            Inlet Temperature (°F):    150.71
             Exit Temperature (°F):     93.28
             Inlet Pressure (psia):    338.29
              Exit Pressure (psia):    335.53
              Pressure Drop (psid):      2.77
              Exit Subcooling (°F):      3.40
       Inlet Sat. Temperature (°F):    101.59
        Condenser Capacity (Btu/h):   37679.2
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):     95.74
        Cond Unit Exit Pres (psia):    328.17
     Liq-line Pressure Drop (psid):     13.61
      TXV Upstream Pressure (psia):    314.56
          TXV Pressure Drop (psid):    148.35
             Temperature Drop (°F):      0.98
(COMPRESSOR)
         Suction Temperature (°F):     72.91
       Discharge Temperature (°F):    154.39
           Suction Pressure (psia):    153.10
         Discharge Pressure (psia):    339.25
          Discharge Superheat (°F):     52.87
       Comp Bottom Shell Temp (°F):    114.01
            Mass Flow Rate (lbm/h):    419.53
        Comp Power Consumption (W):    1736.2
          Cond Unit Inlet Temp (°F):     71.25
       Cond Unit Inlet Pres (psia):    154.28
```

```
        HEAT PUMP FAULT TEST SUMMARY

      INDOOR/OUTDOOR CONDITION #: 05
 FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
           FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.77
  Indoor Dry-Bulb Temperature (°F):     80.13
 Indoor Dew-Point Temperature (°F):     60.34
 Outdoor Dry-Bulb Temperature (°F):     81.81
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.13
  Inlet Dew-Point Temperature (°F):     60.34
    Exit Dry-Bulb Temperature (°F):     61.23
   Exit Dew-Point Temperature (°F):     56.95
       Inlet Relative Humidity (-):     0.509
        Exit Relative Humidity (-):     0.858
    Evaporator Coil Temp Drop (°F):     18.90
              Air Flow Rate (SCFM):     988.4
          Fan Power Consumption (W):   414.82
(OUTDOOR UNIT)
             Inlet Temperature (°F):    81.81
              Exit Temperature (°F):    97.16
    Condensing Unit Temp Gain (°F):     15.35
          Fan Power Consumption (W):   158.13
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    6168.5
         Sensible Capacity (Btu/h):   20565.3
          Overall Capacity (Btu/h):   26733.8
            Sensible Heat Ratio (-):    0.769
      Overall Power Consumption (W):   2293.9
         NET Cooling EER (Btu/h.W):     11.65
   Evaporator Energy Imbalance (%):      6.80
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    48.88
              Exit Temperature (°F):    70.22
              Inlet Pressure (psia):   154.32
               Exit Pressure (psia):   144.20
               Pressure Drop (psid):    10.12
                Exit Superheat (°F):    25.35
        Exit Sat. Temperature (°F):     44.87
      Evaporator Capacity (Btu/h):    29128.0
(CONDENSER)
             Inlet Temperature (°F):   155.38
              Exit Temperature (°F):    94.51
              Inlet Pressure (psia):   331.79
               Exit Pressure (psia):   329.31
               Pressure Drop (psid):     2.48
               Exit Subcooling (°F):     1.55
       Inlet Sat. Temperature (°F):    100.16
       Condenser Capacity (Btu/h):    35967.3
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    96.48
        Cond Unit Exit Pres (psia):    323.16
     Liq-line Pressure Drop (psid):     11.63
      TXV Upstream Pressure (psia):    311.53
          TXV Pressure Drop (psid):    157.21
             Temperature Drop (°F):      2.20
(COMPRESSOR)
          Suction Temperature (°F):     73.65
        Discharge Temperature (°F):    159.89
            Suction Pressure (psia):   141.99
          Discharge Pressure (psia):   332.76
           Discharge Superheat (°F):    59.78
       Comp Bottom Shell Temp (°F):    118.72
             Mass Flow Rate (lbm/h):   393.74
       Comp Power Consumption (W):     1720.9
          Cond Unit Inlet Temp (°F):    71.73
       Cond Unit Inlet Pres (psia):    143.18
```

```
        HEAT PUMP FAULT TEST SUMMARY

      INDOOR/OUTDOOR CONDITION #: 05
 FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
           FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.12
  Indoor Dry-Bulb Temperature (°F):     79.90
 Indoor Dew-Point Temperature (°F):     60.71
 Outdoor Dry-Bulb Temperature (°F):     81.87
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.90
  Inlet Dew-Point Temperature (°F):     60.71
    Exit Dry-Bulb Temperature (°F):     62.52
   Exit Dew-Point Temperature (°F):     57.83
       Inlet Relative Humidity (-):     0.520
        Exit Relative Humidity (-):     0.846
    Evaporator Coil Temp Drop (°F):     17.39
              Air Flow Rate (SCFM):    1006.9
          Fan Power Consumption (W):   418.47
(OUTDOOR UNIT)
             Inlet Temperature (°F):    81.87
              Exit Temperature (°F):    95.89
    Condensing Unit Temp Gain (°F):     14.02
          Fan Power Consumption (W):   158.95
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    5383.2
         Sensible Capacity (Btu/h):   19281.0
          Overall Capacity (Btu/h):   24664.2
            Sensible Heat Ratio (-):    0.782
      Overall Power Consumption (W):   2269.7
         NET Cooling EER (Btu/h.W):     10.87
   Evaporator Energy Imbalance (%):     -0.99
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    45.32
              Exit Temperature (°F):    70.96
              Inlet Pressure .(psia):  142.95
               Exit Pressure (psia):   133.74
               Pressure Drop (psid):     9.21
                Exit Superheat (°F):    30.56
        Exit Sat. Temperature (°F):     40.40
      Evaporator Capacity (Btu/h):    24836.1
(CONDENSER)
             Inlet Temperature (°F):   159.91
              Exit Temperature (°F):    94.40
              Inlet Pressure (psia):   324.11
               Exit Pressure (psia):   321.81
               Pressure Drop (psid):     2.30
               Exit Subcooling (°F):     1.34
       Inlet Sat. Temperature (°F):     98.46
       Condenser Capacity (Btu/h):    31162.1
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    95.00
        Cond Unit Exit Pres (psia):    315.71
     Liq-line Pressure Drop (psid):     11.88
      TXV Upstream Pressure (psia):    303.83
          TXV Pressure Drop (psid):    160.88
             Temperature Drop (°F):      2.40
(COMPRESSOR)
          Suction Temperature (°F):     74.86
        Discharge Temperature (°F):    165.34
            Suction Pressure (psia):   131.62
          Discharge Pressure (psia):   324.87
           Discharge Superheat (°F):    66.98
       Comp Bottom Shell Temp (°F):    122.43
             Mass Flow Rate (lbm/h):   332.07
       Comp Power Consumption (W):     1692.3
          Cond Unit Inlet Temp (°F):    72.52
       Cond Unit Inlet Pres (psia):    132.86
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 08
  FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
             FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
         Barometric Pressure (inHg):    30.33
  Indoor Dry-Bulb Temperature (°F):     70.00
 Indoor Dew-Point Temperature (°F):     50.60
 Outdoor Dry-Bulb Temperature (°F):    100.28
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.00
  Inlet Dew-Point Temperature (°F):     50.60
    Exit Dry-Bulb Temperature (°F):     52.57
   Exit Dew-Point Temperature (°F):     48.76
       Inlet Relative Humidity (-):     0.501
        Exit Relative Humidity (-):     0.868
    Evaporator Coil Temp Drop (°F):     17.43
              Air Flow Rate (SCFM):    1026.3
         Fan Power Consumption (W):    421.19
(OUTDOOR UNIT)
            Inlet Temperature (°F):    100.28
             Exit Temperature (°F):    114.77
    Condensing Unit Temp Gain (°F):     14.49
         Fan Power Consumption (W):    155.11
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2523.8
         Sensible Capacity (Btu/h):   19586.3
          Overall Capacity (Btu/h):   22110.1
           Sensible Heat Ratio (-):     0.886
     Overall Power Consumption (W):    2771.8
         NET Cooling EER (Btu/h.W):      7.98
   Evaporator Energy Imbalance (%):      3.97
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     47.81
             Exit Temperature (°F):     57.82
             Inlet Pressure (psia):    155.22
              Exit Pressure (psia):    143.18
              Pressure Drop (psid):     12.04
               Exit Superheat (°F):     13.37
         Exit Sat. Temperature (°F):    44.45
      Evaporator Capacity (Btu/h):    23461.8
(CONDENSER)
            Inlet Temperature (°F):    176.08
             Exit Temperature (°F):    113.15
             Inlet Pressure (psia):    417.08
              Exit Pressure (psia):    414.97
              Pressure Drop (psid):      2.11
              Exit Subcooling (°F):      0.94
       Inlet Sat. Temperature (°F):    117.33
       Condenser Capacity (Btu/h):    32141.0
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   114.55
         Cond Unit Exit Pres (psia):   408.29
      Liq-line Pressure Drop (psid):    11.62
       TXV Upstream Pressure (psia):   396.67
           TXV Pressure Drop (psid):   241.44
             Temperature Drop (°F):      1.91
(COMPRESSOR)
           Suction Temperature (°F):    64.51
         Discharge Temperature (°F):   181.09
            Suction Pressure (psia):   141.11
          Discharge Pressure (psia):   417.99
           Discharge Superheat (°F):    63.83
         Comp Bottom Shell Temp (°F):  126.81
              Mass Flow Rate (lbm/h):  375.23
       Comp Power Consumption (W):    2195.5
          Cond Unit Inlet Temp (°F):    60.40
        Cond Unit Inlet Pres (psia):   142.35
```

```
         HEAT PUMP FAULT TEST SUMMARY

        INDOOR/OUTDOOR CONDITION #: 08
  FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
             FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
         Barometric Pressure (inHg):    30.37
  Indoor Dry-Bulb Temperature (°F):     69.80
 Indoor Dew-Point Temperature (°F):     50.28
 Outdoor Dry-Bulb Temperature (°F):     99.91
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.80
  Inlet Dew-Point Temperature (°F):     50.28
    Exit Dry-Bulb Temperature (°F):     52.59
   Exit Dew-Point Temperature (°F):     48.20
       Inlet Relative Humidity (-):     0.499
        Exit Relative Humidity (-):     0.849
    Evaporator Coil Temp Drop (°F):     17.21
              Air Flow Rate (SCFM):    1029.1
         Fan Power Consumption (W):    424.20
(OUTDOOR UNIT)
            Inlet Temperature (°F):     99.91
             Exit Temperature (°F):    114.05
    Condensing Unit Temp Gain (°F):     14.14
         Fan Power Consumption (W):    156.75
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2828.5
         Sensible Capacity (Btu/h):   19386.1
          Overall Capacity (Btu/h):   22214.6
           Sensible Heat Ratio (-):     0.873
     Overall Power Consumption (W):    2751.6
         NET Cooling EER (Btu/h.W):      8.07
   Evaporator Energy Imbalance (%):      1.29
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):     47.16
             Exit Temperature (°F):     58.14
             Inlet Pressure (psia):    153.89
              Exit Pressure (psia):    141.60
              Pressure Drop (psid):     12.30
               Exit Superheat (°F):     14.36
         Exit Sat. Temperature (°F):    43.78
      Evaporator Capacity (Btu/h):    22935.0
(CONDENSER)
            Inlet Temperature (°F):    176.01
             Exit Temperature (°F):    113.48
             Inlet Pressure (psia):    411.89
              Exit Pressure (psia):    409.71
              Pressure Drop (psid):      2.19
              Exit Subcooling (°F):      0.90
       Inlet Sat. Temperature (°F):    116.36
       Condenser Capacity (Btu/h):    31419.9
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   113.46
         Cond Unit Exit Pres (psia):   402.27
      Liq-line Pressure Drop (psid):    13.90
       TXV Upstream Pressure (psia):   388.38
           TXV Pressure Drop (psid):   234.48
             Temperature Drop (°F):      2.24
(COMPRESSOR)
           Suction Temperature (°F):    65.00
         Discharge Temperature (°F):   181.25
            Suction Pressure (psia):   139.52
          Discharge Pressure (psia):   412.78
           Discharge Superheat (°F):    64.95
         Comp Bottom Shell Temp (°F):  127.21
              Mass Flow Rate (lbm/h):  363.53
       Comp Power Consumption (W):    2170.6
          Cond Unit Inlet Temp (°F):    60.79
        Cond Unit Inlet Pres (psia):   140.69
```

```
             HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 08
      FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
                FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    29.98
  Indoor Dry-Bulb Temperature (°F):    69.87
 Indoor Dew-Point Temperature (°F):    50.62
 Outdoor Dry-Bulb Temperature (°F):    99.78
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    69.87
  Inlet Dew-Point Temperature (°F):    50.62
    Exit Dry-Bulb Temperature (°F):    53.29
   Exit Dew-Point Temperature (°F):    48.73
       Inlet Relative Humidity (-):    0.504
        Exit Relative Humidity (-):    0.844
    Evaporator Coil Temp Drop (°F):    16.58
              Air Flow Rate (SCFM):   1017.8
         Fan Power Consumption (W):   423.70
(OUTDOOR UNIT)
             Inlet Temperature (°F):   99.78
              Exit Temperature (°F):  113.23
    Condensing Unit Temp Gain (°F):    13.45
         Fan Power Consumption (W):   156.05
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   2608.3
         Sensible Capacity (Btu/h):  18478.4
          Overall Capacity (Btu/h):  21086.7
           Sensible Heat Ratio (-):    0.876
     Overall Power Consumption (W):   2726.1
         NET Cooling EER (Btu/h.W):     7.74
   Evaporator Energy Imbalance (%):     0.28
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):   44.79
              Exit Temperature (°F):   61.41
              Inlet Pressure (psia):  146.27
               Exit Pressure (psia):  135.01
               Pressure Drop (psid):   11.27
                Exit Superheat (°F):   20.45
         Exit Sat. Temperature (°F):   40.96
      Evaporator Capacity (Btu/h):   21569.9
(CONDENSER)
             Inlet Temperature (°F):  182.08
              Exit Temperature (°F):  113.03
              Inlet Pressure (psia):  405.55
               Exit Pressure (psia):  403.47
               Pressure Drop (psid):    2.08
               Exit Subcooling (°F):    0.71
        Inlet Sat. Temperature (°F):  115.18
        Condenser Capacity (Btu/h):  29799.4
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   112.38
         Cond Unit Exit Pres (psia):  395.66
     Liq-line Pressure Drop (psid):    14.42
      TXV Upstream Pressure (psia):   381.23
          TXV Pressure Drop (psid):   234.96
             Temperature Drop (°F):     2.39
(COMPRESSOR)
          Suction Temperature (°F):    68.76
        Discharge Temperature (°F):   188.17
            Suction Pressure (psia):  133.03
          Discharge Pressure (psia):  406.52
           Discharge Superheat (°F):   73.05
        Comp Bottom Shell Temp (°F):  133.96
            Mass Flow Rate (lbm/h):   334.03
        Comp Power Consumption (W):   2146.3
          Cond Unit Inlet Temp (°F):   64.16
        Cond Unit Inlet Pres (psia):  134.25
```

```
             HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 09
      FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
                FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.38
  Indoor Dry-Bulb Temperature (°F):    79.92
 Indoor Dew-Point Temperature (°F):    60.18
 Outdoor Dry-Bulb Temperature (°F):    99.29
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    79.92
  Inlet Dew-Point Temperature (°F):    60.18
    Exit Dry-Bulb Temperature (°F):    61.11
   Exit Dew-Point Temperature (°F):    57.38
       Inlet Relative Humidity (-):    0.510
        Exit Relative Humidity (-):    0.875
    Evaporator Coil Temp Drop (°F):    18.82
              Air Flow Rate (SCFM):   1006.2
         Fan Power Consumption (W):   415.59
(OUTDOOR UNIT)
             Inlet Temperature (°F):   99.29
              Exit Temperature (°F):  115.59
    Condensing Unit Temp Gain (°F):    16.30
         Fan Power Consumption (W):   155.24
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   5086.7
         Sensible Capacity (Btu/h):  20840.6
          Overall Capacity (Btu/h):  25927.3
           Sensible Heat Ratio (-):    0.804
     Overall Power Consumption (W):   2767.3
         NET Cooling EER (Btu/h.W):     9.37
   Evaporator Energy Imbalance (%):     4.64
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):   55.27
              Exit Temperature (°F):   69.02
              Inlet Pressure (psia):  175.14
               Exit Pressure (psia):  161.94
               Pressure Drop (psid):   13.20
                Exit Superheat (°F):   17.11
         Exit Sat. Temperature (°F):   51.92
      Evaporator Capacity (Btu/h):   27624.8
(CONDENSER)
             Inlet Temperature (°F):  174.67
              Exit Temperature (°F):  113.53
              Inlet Pressure (psia):  422.87
               Exit Pressure (psia):  420.44
               Pressure Drop (psid):    2.43
               Exit Subcooling (°F):    1.09
        Inlet Sat. Temperature (°F):  118.39
        Condenser Capacity (Btu/h):  36243.1
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   115.12
         Cond Unit Exit Pres (psia):  412.12
     Liq-line Pressure Drop (psid):    15.74
      TXV Upstream Pressure (psia):   396.38
          TXV Pressure Drop (psid):   221.24
             Temperature Drop (°F):     2.37
(COMPRESSOR)
          Suction Temperature (°F):    73.81
        Discharge Temperature (°F):   178.70
            Suction Pressure (psia):  159.71
          Discharge Pressure (psia):  423.63
           Discharge Superheat (°F):   60.40
        Comp Bottom Shell Temp (°F):  126.66
            Mass Flow Rate (lbm/h):   429.29
        Comp Power Consumption (W):   2196.5
          Cond Unit Inlet Temp (°F):   70.92
        Cond Unit Inlet Pres (psia):  160.86
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 09
       FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
                 FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     29.51
  Indoor Dry-Bulb Temperature (°F):     79.95
 Indoor Dew-Point Temperature (°F):     60.56
 Outdoor Dry-Bulb Temperature (°F):     99.78
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.95
  Inlet Dew-Point Temperature (°F):     60.56
    Exit Dry-Bulb Temperature (°F):     62.07
   Exit Dew-Point Temperature (°F):     57.74
       Inlet Relative Humidity (-):     0.516
        Exit Relative Humidity (-):     0.857
    Evaporator Coil Temp Drop (°F):     17.88
             Air Flow Rate (SCFM):      980.1
        Fan Power Consumption (W):     414.03
(OUTDOOR UNIT)
             Inlet Temperature (°F):    99.78
              Exit Temperature (°F):   115.58
    Condensing Unit Temp Gain (°F):     15.81
        Fan Power Consumption (W):     154.61
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):     5212.2
        Sensible Capacity (Btu/h):    19311.4
         Overall Capacity (Btu/h):    24523.6
          Sensible Heat Ratio (-):      0.787
    Overall Power Consumption (W):     2776.7
        NET Cooling EER (Btu/h.W):       8.83
   Evaporator Energy Imbalance (%):      4.74
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    52.50
              Exit Temperature (°F):    70.70
              Inlet Pressure (psia):   166.94
               Exit Pressure (psia):   154.37
               Pressure Drop (psid):    12.57
                Exit Superheat (°F):    21.72
        Exit Sat. Temperature (°F):     48.98
      Evaporator Capacity (Btu/h):    26177.5
(CONDENSER)
             Inlet Temperature (°F):   180.82
              Exit Temperature (°F):   114.62
              Inlet Pressure (psia):   420.94
               Exit Pressure (psia):   418.64
               Pressure Drop (psid):     2.30
               Exit Subcooling (°F):     0.95
       Inlet Sat. Temperature (°F):    118.04
        Condenser Capacity (Btu/h):   34794.6
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   115.06
        Cond Unit Exit Pres (psia):    411.04
     Liq-line Pressure Drop (psid):     15.03
      TXV Upstream Pressure (psia):    396.01
          TXV Pressure Drop (psid):    229.08
              Temperature Drop (°F):     2.25
(COMPRESSOR)
           Suction Temperature (°F):    75.91
        Discharge Temperature (°F):    185.60
           Suction Pressure (psia):    152.22
         Discharge Pressure (psia):    421.80
           Discharge Superheat (°F):    67.63
       Comp Bottom Shell Temp (°F):    133.42
           Mass Flow Rate (lbm/h):     401.82
       Comp Power Consumption (W):     2208.0
          Cond Unit Inlet Temp (°F):    72.78
       Cond Unit Inlet Pres (psia):    153.39
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 09
       FAULT TYPE: REFRIGERANT UNDERCHARGE FAULT
                 FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.01
  Indoor Dry-Bulb Temperature (°F):     79.85
 Indoor Dew-Point Temperature (°F):     60.56
 Outdoor Dry-Bulb Temperature (°F):     99.89
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.85
  Inlet Dew-Point Temperature (°F):     60.56
    Exit Dry-Bulb Temperature (°F):     63.06
   Exit Dew-Point Temperature (°F):     58.36
       Inlet Relative Humidity (-):     0.518
        Exit Relative Humidity (-):     0.846
    Evaporator Coil Temp Drop (°F):     16.79
             Air Flow Rate (SCFM):     1000.3
        Fan Power Consumption (W):     419.79
(OUTDOOR UNIT)
             Inlet Temperature (°F):    99.89
              Exit Temperature (°F):   114.14
    Condensing Unit Temp Gain (°F):     14.25
        Fan Power Consumption (W):     156.28
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):     4121.4
        Sensible Capacity (Btu/h):    18506.7
         Overall Capacity (Btu/h):    22628.1
          Sensible Heat Ratio (-):      0.818
    Overall Power Consumption (W):     2743.8
        NET Cooling EER (Btu/h.W):       8.25
   Evaporator Energy Imbalance (%):      0.27
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    48.08
              Exit Temperature (°F):    71.03
              Inlet Pressure (psia):   153.40
               Exit Pressure (psia):   142.24
               Pressure Drop (psid):    11.16
                Exit Superheat (°F):    26.98
        Exit Sat. Temperature (°F):     44.05
      Evaporator Capacity (Btu/h):    23109.5
(CONDENSER)
             Inlet Temperature (°F):   186.53
              Exit Temperature (°F):   113.86
              Inlet Pressure (psia):   410.71
               Exit Pressure (psia):   408.56
               Pressure Drop (psid):     2.15
               Exit Subcooling (°F):     0.81
       Inlet Sat. Temperature (°F):    116.14
        Condenser Capacity (Btu/h):   31316.3
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   113.31
        Cond Unit Exit Pres (psia):    400.99
     Liq-line Pressure Drop (psid):     14.82
      TXV Upstream Pressure (psia):    386.17
          TXV Pressure Drop (psid):    232.77
              Temperature Drop (°F):     2.39
(COMPRESSOR)
           Suction Temperature (°F):    77.11
        Discharge Temperature (°F):    192.49
           Suction Pressure (psia):    140.19
         Discharge Pressure (psia):    411.35
           Discharge Superheat (°F):    76.46
       Comp Bottom Shell Temp (°F):    139.07
           Mass Flow Rate (lbm/h):     348.62
       Comp Power Consumption (W):     2167.7
          Cond Unit Inlet Temp (°F):    73.32
       Cond Unit Inlet Pres (psia):    141.34
```

D.7 Refrigerant Overcharge Fault Tests

Table D.7. List of raw data for refrigerant overcharge fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	OC	10.0
4	70	50	82	OC	20.0
4	70	50	82	OC	30.0
5	80	50	82	OC	10.0
5	80	50	82	OC	20.0
5	80	50	82	OC	30.0
8	70	50	100	OC	10.0
8	70	50	100	OC	20.0
8	70	50	100	OC	30.0
9	80	50	100	OC	10.0
9	80	50	100	OC	20.0
9	80	50	100	OC	30.0

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
              FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.31
  Indoor Dry-Bulb Temperature (°F):    70.09
 Indoor Dew-Point Temperature (°F):    50.63
 Outdoor Dry-Bulb Temperature (°F):    81.92
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.09
  Inlet Dew-Point Temperature (°F):    50.63
    Exit Dry-Bulb Temperature (°F):    50.99
   Exit Dew-Point Temperature (°F):    47.57
        Inlet Relative Humidity (-):   0.500
         Exit Relative Humidity (-):   0.880
     Evaporator Coil Temp Drop (°F):   19.10
              Air Flow Rate (SCFM):   1027.8
        Fan Power Consumption (W):    426.17
(OUTDOOR UNIT)
              Inlet Temperature (°F):  81.92
               Exit Temperature (°F):  97.01
    Condensing Unit Temp Gain (°F):    15.09
        Fan Power Consumption (W):    160.18
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4123.1
         Sensible Capacity (Btu/h):  21482.0
          Overall Capacity (Btu/h):  25605.1
           Sensible Heat Ratio (-):    0.839
     Overall Power Consumption (W):   2342.0
         NET Cooling EER (Btu/h.W):    10.93
   Evaporator Energy Imbalance (%):     7.22
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):  46.45
               Exit Temperature (°F):  56.18
               Inlet Pressure (psia): 149.35
                Exit Pressure (psia): 139.71
                Pressure Drop (psid):   9.63
                 Exit Superheat (°F):  13.20
        Exit Sat. Temperature (°F):    42.99
      Evaporator Capacity (Btu/h):   28058.3
(CONDENSER)
              Inlet Temperature (°F): 148.41
               Exit Temperature (°F):  88.71
               Inlet Pressure (psia): 338.11
                Exit Pressure (psia): 336.02
                Pressure Drop (psid):   2.09
                Exit Subcooling (°F):  10.84
      Inlet Sat. Temperature (°F):    101.55
       Condenser Capacity (Btu/h):   35085.1
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):  88.72
        Cond Unit Exit Pres (psia):   330.01
     Liq-line Pressure Drop (psid):    10.65
      TXV Upstream Pressure (psia):   319.36
           TXV Pressure Drop (psid):  170.02
               Temperature Drop (°F):   0.77
(COMPRESSOR)
          Suction Temperature (°F):    61.05
        Discharge Temperature (°F):   152.56
           Suction Pressure (psia):   137.51
         Discharge Pressure (psia):   339.21
           Discharge Superheat (°F):   51.05
      Comp Bottom Shell Temp (°F):    108.81
            Mass Flow Rate (lbm/h):   380.01
        Comp Power Consumption (W):   1755.7
         Cond Unit Inlet Temp (°F):    58.21
      Cond Unit Inlet Pres (psia):    138.73
```

```
          HEAT PUMP FAULT TEST SUMMARY

         INDOOR/OUTDOOR CONDITION #: 04
    FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
              FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.44
  Indoor Dry-Bulb Temperature (°F):    70.33
 Indoor Dew-Point Temperature (°F):    50.43
 Outdoor Dry-Bulb Temperature (°F):    81.79
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.33
  Inlet Dew-Point Temperature (°F):    50.43
    Exit Dry-Bulb Temperature (°F):    50.86
   Exit Dew-Point Temperature (°F):    47.03
        Inlet Relative Humidity (-):   0.493
         Exit Relative Humidity (-):   0.867
     Evaporator Coil Temp Drop (°F):   19.47
              Air Flow Rate (SCFM):   1032.4
        Fan Power Consumption (W):    421.13
(OUTDOOR UNIT)
              Inlet Temperature (°F):  81.79
               Exit Temperature (°F):  96.74
    Condensing Unit Temp Gain (°F):    14.96
        Fan Power Consumption (W):    159.59
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   4533.8
         Sensible Capacity (Btu/h):  22001.0
          Overall Capacity (Btu/h):  26534.8
           Sensible Heat Ratio (-):    0.829
     Overall Power Consumption (W):   2365.9
         NET Cooling EER (Btu/h.W):    11.22
   Evaporator Energy Imbalance (%):     4.06
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):  46.11
               Exit Temperature (°F):  55.16
               Inlet Pressure (psia): 148.29
                Exit Pressure (psia): 138.66
                Pressure Drop (psid):   9.63
                 Exit Superheat (°F):  12.62
        Exit Sat. Temperature (°F):    42.54
      Evaporator Capacity (Btu/h):   28095.8
(CONDENSER)
              Inlet Temperature (°F): 149.60
               Exit Temperature (°F):  87.44
               Inlet Pressure (psia): 342.92
                Exit Pressure (psia): 340.99
                Pressure Drop (psid):   1.93
                Exit Subcooling (°F):  13.65
      Inlet Sat. Temperature (°F):    102.59
       Condenser Capacity (Btu/h):   35197.9
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):  87.05
        Cond Unit Exit Pres (psia):   335.19
     Liq-line Pressure Drop (psid):    10.42
      TXV Upstream Pressure (psia):   324.77
           TXV Pressure Drop (psid):  176.48
               Temperature Drop (°F):   0.69
(COMPRESSOR)
          Suction Temperature (°F):    60.26
        Discharge Temperature (°F):   153.88
           Suction Pressure (psia):   136.56
         Discharge Pressure (psia):   343.94
           Discharge Superheat (°F):   51.34
      Comp Bottom Shell Temp (°F):    109.07
            Mass Flow Rate (lbm/h):   377.70
        Comp Power Consumption (W):   1785.2
         Cond Unit Inlet Temp (°F):    57.37
      Cond Unit Inlet Pres (psia):    137.81
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 04
  FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
          FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.28
  Indoor Dry-Bulb Temperature (°F):     70.08
 Indoor Dew-Point Temperature (°F):     50.99
 Outdoor Dry-Bulb Temperature (°F):     82.21
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.08
  Inlet Dew-Point Temperature (°F):     50.99
    Exit Dry-Bulb Temperature (°F):     50.83
   Exit Dew-Point Temperature (°F):     47.58
       Inlet Relative Humidity (-):     0.507
        Exit Relative Humidity (-):     0.885
     Evaporator Coil Temp Drop (°F):    19.25
               Air Flow Rate (SCFM):   1026.0
          Fan Power Consumption (W):   420.00
(OUTDOOR UNIT)
               Inlet Temperature (°F):  82.21
                Exit Temperature (°F):  97.29
     Condensing Unit Temp Gain (°F):    15.08
          Fan Power Consumption (W):   158.81
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):  4630.6
           Sensible Capacity (Btu/h): 21623.1
            Overall Capacity (Btu/h): 26253.7
             Sensible Heat Ratio (-):   0.824
      Overall Power Consumption (W):   2418.2
           NET Cooling EER (Btu/h.W):   10.86
   Evaporator Energy Imbalance (%):      5.53
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):  46.40
                Exit Temperature (°F):  55.51
                Inlet Pressure (psia): 148.92
                 Exit Pressure (psia): 139.70
                 Pressure Drop (psid):   9.22
                  Exit Superheat (°F):  12.53
           Exit Sat. Temperature (°F):  42.98
         Evaporator Capacity (Btu/h): 28236.0
(CONDENSER)
               Inlet Temperature (°F): 152.67
                Exit Temperature (°F):  87.69
                Inlet Pressure (psia): 353.92
                 Exit Pressure (psia): 352.12
                 Pressure Drop (psid):   1.80
                 Exit Subcooling (°F):  15.98
          Inlet Sat. Temperature (°F): 104.92
          Condenser Capacity (Btu/h): 35495.2
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):  87.11
           Cond Unit Exit Pres (psia): 346.24
        Liq-line Pressure Drop (psid):  10.56
         TXV Upstream Pressure (psia): 335.68
             TXV Pressure Drop (psid): 186.76
                Temperature Drop (°F):   0.69
(COMPRESSOR)
             Suction Temperature (°F):  60.66
           Discharge Temperature (°F): 156.95
              Suction Pressure (psia): 137.58
            Discharge Pressure (psia): 354.91
             Discharge Superheat (°F):  52.08
         Comp Bottom Shell Temp (°F):  110.60
               Mass Flow Rate (lbm/h): 379.41
          Comp Power Consumption (W): 1839.4
            Cond Unit Inlet Temp (°F):  57.70
         Cond Unit Inlet Pres (psia):  138.83
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 05
  FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
          FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.74
  Indoor Dry-Bulb Temperature (°F):     80.03
 Indoor Dew-Point Temperature (°F):     60.49
 Outdoor Dry-Bulb Temperature (°F):     81.77
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     80.03
  Inlet Dew-Point Temperature (°F):     60.49
    Exit Dry-Bulb Temperature (°F):     59.87
   Exit Dew-Point Temperature (°F):     56.71
       Inlet Relative Humidity (-):     0.514
        Exit Relative Humidity (-):     0.893
     Evaporator Coil Temp Drop (°F):    20.16
               Air Flow Rate (SCFM):   1017.0
          Fan Power Consumption (W):   417.27
(OUTDOOR UNIT)
               Inlet Temperature (°F):  81.77
                Exit Temperature (°F):  98.84
     Condensing Unit Temp Gain (°F):    17.07
          Fan Power Consumption (W):   158.93
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):  6835.6
           Sensible Capacity (Btu/h): 22562.4
            Overall Capacity (Btu/h): 29398.0
             Sensible Heat Ratio (-):   0.767
      Overall Power Consumption (W):   2352.0
           NET Cooling EER (Btu/h.W):   12.50
   Evaporator Energy Imbalance (%):      9.58
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):  54.94
                Exit Temperature (°F):  66.64
                Inlet Pressure (psia): 170.67
                 Exit Pressure (psia): 159.91
                 Pressure Drop (psid):  10.76
                  Exit Superheat (°F):  15.50
           Exit Sat. Temperature (°F):  51.14
         Evaporator Capacity (Btu/h): 32975.3
(CONDENSER)
               Inlet Temperature (°F): 148.29
                Exit Temperature (°F):  89.43
                Inlet Pressure (psia): 348.25
                 Exit Pressure (psia): 345.72
                 Pressure Drop (psid):   2.53
                 Exit Subcooling (°F):  11.41
          Inlet Sat. Temperature (°F): 103.72
          Condenser Capacity (Btu/h): 39940.5
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):  89.93
           Cond Unit Exit Pres (psia): 338.16
        Liq-line Pressure Drop (psid):  14.67
         TXV Upstream Pressure (psia): 323.49
             TXV Pressure Drop (psid): 152.82
                Temperature Drop (°F):   0.39
(COMPRESSOR)
             Suction Temperature (°F):  69.74
           Discharge Temperature (°F): 151.54
              Suction Pressure (psia): 157.65
            Discharge Pressure (psia): 349.04
             Discharge Superheat (°F):  47.91
         Comp Bottom Shell Temp (°F):  110.20
               Mass Flow Rate (lbm/h): 438.77
          Comp Power Consumption (W): 1775.8
            Cond Unit Inlet Temp (°F):  68.08
         Cond Unit Inlet Pres (psia):  158.78
```

HEAT PUMP FAULT TEST SUMMARY

INDOOR/OUTDOOR CONDITION #: 05
FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
FAULT LEVEL [%]: 20.0

RUNNING CONDITIONS

Barometric Pressure (inHg):	30.42
Indoor Dry-Bulb Temperature (°F):	80.01
Indoor Dew-Point Temperature (°F):	60.24
Outdoor Dry-Bulb Temperature (°F):	81.66

AIR SIDE CONDITIONS

(INDOOR UNIT)

Inlet Dry-Bulb Temperature (°F):	80.01
Inlet Dew-Point Temperature (°F):	60.24
Exit Dry-Bulb Temperature (°F):	59.17
Exit Dew-Point Temperature (°F):	56.22
Inlet Relative Humidity (-):	0.510
Exit Relative Humidity (-):	0.899
Evaporator Coil Temp Drop (°F):	20.84
Air Flow Rate (SCFM):	1012.3
Fan Power Consumption (W):	413.24

(OUTDOOR UNIT)

Inlet Temperature (°F):	81.66
Exit Temperature (°F):	98.74
Condensing Unit Temp Gain (°F):	17.08
Fan Power Consumption (W):	158.62

(OVERALL PERFORMANCE)

Latent Capacity (Btu/h):	7227.7
Sensible Capacity (Btu/h):	23217.1
Overall Capacity (Btu/h):	30444.7
Sensible Heat Ratio (-):	0.763
Overall Power Consumption (W):	2385.2
NET Cooling EER (Btu/h.W):	12.76
Evaporator Energy Imbalance (%):	6.49

REFRIGERANT SIDE CONDITIONS

(EVAPORATOR)

Inlet Temperature (°F):	54.03
Exit Temperature (°F):	65.23
Inlet Pressure (psia):	168.97
Exit Pressure (psia):	158.66
Pressure Drop (psid):	10.31
Exit Superheat (°F):	14.58
Exit Sat. Temperature (°F):	50.66
Evaporator Capacity (Btu/h):	33001.2

(CONDENSER)

Inlet Temperature (°F):	149.51
Exit Temperature (°F):	88.14
Inlet Pressure (psia):	354.57
Exit Pressure (psia):	352.27
Pressure Drop (psid):	2.30
Exit Subcooling (°F):	14.74
Inlet Sat. Temperature (°F):	105.06
Condenser Capacity (Btu/h):	40080.4

(LIQUID LINE AND TXV)

Cond Unit Exit Temp (°F):	88.02
Cond Unit Exit Pres (psia):	344.72
Liq-line Pressure Drop (psid):	14.20
TXV Upstream Pressure (psia):	330.52
TXV Pressure Drop (psid):	161.55
Temperature Drop (°F):	0.34

(COMPRESSOR)

Suction Temperature (°F):	68.50
Discharge Temperature (°F):	152.90
Suction Pressure (psia):	156.43
Discharge Pressure (psia):	355.53
Discharge Superheat (°F):	47.91
Comp Bottom Shell Temp (°F):	110.19
Mass Flow Rate (lbm/h):	435.95
Comp Power Consumption (W):	1813.3
Cond Unit Inlet Temp (°F):	66.76
Cond Unit Inlet Pres (psia):	157.59

HEAT PUMP FAULT TEST SUMMARY

INDOOR/OUTDOOR CONDITION #: 05
FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
FAULT LEVEL [%]: 30.0

RUNNING CONDITIONS

Barometric Pressure (inHg):	30.07
Indoor Dry-Bulb Temperature (°F):	79.94
Indoor Dew-Point Temperature (°F):	60.48
Outdoor Dry-Bulb Temperature (°F):	81.78

AIR SIDE CONDITIONS

(INDOOR UNIT)

Inlet Dry-Bulb Temperature (°F):	79.94
Inlet Dew-Point Temperature (°F):	60.48
Exit Dry-Bulb Temperature (°F):	58.88
Exit Dew-Point Temperature (°F):	56.07
Inlet Relative Humidity (-):	0.515
Exit Relative Humidity (-):	0.904
Evaporator Coil Temp Drop (°F):	21.06
Air Flow Rate (SCFM):	999.2
Fan Power Consumption (W):	426.19

(OUTDOOR UNIT)

Inlet Temperature (°F):	81.78
Exit Temperature (°F):	98.90
Condensing Unit Temp Gain (°F):	17.12
Fan Power Consumption (W):	161.90

(OVERALL PERFORMANCE)

Latent Capacity (Btu/h):	7929.7
Sensible Capacity (Btu/h):	23163.4
Overall Capacity (Btu/h):	31093.1
Sensible Heat Ratio (-):	0.745
Overall Power Consumption (W):	2452.7
NET Cooling EER (Btu/h.W):	12.68
Evaporator Energy Imbalance (%):	4.63

REFRIGERANT SIDE CONDITIONS

(EVAPORATOR)

Inlet Temperature (°F):	53.89
Exit Temperature (°F):	64.66
Inlet Pressure (psia):	168.47
Exit Pressure (psia):	158.44
Pressure Drop (psid):	10.03
Exit Superheat (°F):	14.09
Exit Sat. Temperature (°F):	50.57
Evaporator Capacity (Btu/h):	33048.6

(CONDENSER)

Inlet Temperature (°F):	151.76
Exit Temperature (°F):	87.90
Inlet Pressure (psia):	363.93
Exit Pressure (psia):	361.79
Pressure Drop (psid):	2.14
Exit Subcooling (°F):	17.46
Inlet Sat. Temperature (°F):	106.99
Condenser Capacity (Btu/h):	40320.6

(LIQUID LINE AND TXV)

Cond Unit Exit Temp (°F):	87.35
Cond Unit Exit Pres (psia):	354.39
Liq-line Pressure Drop (psid):	14.33
TXV Upstream Pressure (psia):	340.06
TXV Pressure Drop (psid):	171.60
Temperature Drop (°F):	0.19

(COMPRESSOR)

Suction Temperature (°F):	68.00
Discharge Temperature (°F):	155.12
Suction Pressure (psia):	156.15
Discharge Pressure (psia):	364.63
Discharge Superheat (°F):	48.24
Comp Bottom Shell Temp (°F):	110.96
Mass Flow Rate (lbm/h):	436.20
Comp Power Consumption (W):	1864.6
Cond Unit Inlet Temp (°F):	66.16
Cond Unit Inlet Pres (psia):	157.36

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 08
  FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
           FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.48
  Indoor Dry-Bulb Temperature (°F):    70.17
 Indoor Dew-Point Temperature (°F):    50.38
 Outdoor Dry-Bulb Temperature (°F):    99.91
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.17
  Inlet Dew-Point Temperature (°F):    50.38
    Exit Dry-Bulb Temperature (°F):    51.71
   Exit Dew-Point Temperature (°F):    48.02
       Inlet Relative Humidity (-):    0.494
        Exit Relative Humidity (-):    0.872
     Evaporator Coil Temp Drop (°F):   18.47
              Air Flow Rate (SCFM):   1036.9
          Fan Power Consumption (W):  416.94
(OUTDOOR UNIT)
               Inlet Temperature (°F):  99.91
                Exit Temperature (°F): 114.69
     Condensing Unit Temp Gain (°F):   14.78
          Fan Power Consumption (W):  154.98
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   3216.7
          Sensible Capacity (Btu/h):  20956.3
           Overall Capacity (Btu/h):  24173.0
            Sensible Heat Ratio (-):    0.867
      Overall Power Consumption (W):   2820.0
          NET Cooling EER (Btu/h.W):     8.57
    Evaporator Energy Imbalance (%):    -0.51
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):  48.05
                Exit Temperature (°F):  56.20
                Inlet Pressure (psia): 153.33
                 Exit Pressure (psia): 141.76
                 Pressure Drop (psid):  11.57
                  Exit Superheat (°F):  12.35
          Exit Sat. Temperature (°F):   43.85
        Evaporator Capacity (Btu/h):  24464.2
(CONDENSER)
               Inlet Temperature (°F): 178.02
                Exit Temperature (°F): 107.46
                Inlet Pressure (psia): 425.27
                 Exit Pressure (psia): 423.49
                 Pressure Drop (psid):   1.78
                 Exit Subcooling (°F):  10.18
         Inlet Sat. Temperature (°F):  118.83
          Condenser Capacity (Btu/h):  33287.1
(LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F): 107.04
             Cond Unit Exit Pres (psia): 417.60
      Liq-line Pressure Drop (psid):    11.08
       TXV Upstream Pressure (psia):   406.52
           TXV Pressure Drop (psid):   253.19
                Temperature Drop (°F):    1.34
(COMPRESSOR)
             Suction Temperature (°F):  63.34
          Discharge Temperature (°F):  183.28
             Suction Pressure (psia):  139.80
           Discharge Pressure (psia):  426.18
            Discharge Superheat (°F):   64.52
         Comp Bottom Shell Temp (°F):  127.95
             Mass Flow Rate (lbm/h):   371.49
         Comp Power Consumption (W):   2248.0
            Cond Unit Inlet Temp (°F):   58.90
          Cond Unit Inlet Pres (psia): 141.05
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 08
  FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
           FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.48
  Indoor Dry-Bulb Temperature (°F):    70.18
 Indoor Dew-Point Temperature (°F):    50.22
 Outdoor Dry-Bulb Temperature (°F):    99.86
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.18
  Inlet Dew-Point Temperature (°F):    50.22
    Exit Dry-Bulb Temperature (°F):    51.72
   Exit Dew-Point Temperature (°F):    47.99
       Inlet Relative Humidity (-):    0.491
        Exit Relative Humidity (-):    0.870
     Evaporator Coil Temp Drop (°F):   18.47
              Air Flow Rate (SCFM):   1036.7
          Fan Power Consumption (W):  419.09
(OUTDOOR UNIT)
               Inlet Temperature (°F):  99.86
                Exit Temperature (°F): 114.60
     Condensing Unit Temp Gain (°F):   14.74
          Fan Power Consumption (W):  155.74
(OVERALL PERFORMANCE)
            Latent Capacity (Btu/h):   3021.9
          Sensible Capacity (Btu/h):  20951.8
           Overall Capacity (Btu/h):  23973.7
            Sensible Heat Ratio (-):    0.874
      Overall Power Consumption (W):   2872.3
          NET Cooling EER (Btu/h.W):     8.35
    Evaporator Energy Imbalance (%):     0.85
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):  47.82
                Exit Temperature (°F):  55.94
                Inlet Pressure (psia): 152.63
                 Exit Pressure (psia): 141.34
                 Pressure Drop (psid):  11.29
                  Exit Superheat (°F):  12.26
          Exit Sat. Temperature (°F):   43.67
        Evaporator Capacity (Btu/h):  24603.0
(CONDENSER)
               Inlet Temperature (°F): 180.26
                Exit Temperature (°F): 106.24
                Inlet Pressure (psia): 433.74
                 Exit Pressure (psia): 432.06
                 Pressure Drop (psid):   1.68
                 Exit Subcooling (°F):  13.38
         Inlet Sat. Temperature (°F):  120.35
          Condenser Capacity (Btu/h):  33540.5
(LIQUID LINE AND TXV)
              Cond Unit Exit Temp (°F): 105.44
             Cond Unit Exit Pres (psia): 426.30
      Liq-line Pressure Drop (psid):    10.90
       TXV Upstream Pressure (psia):   415.40
           TXV Pressure Drop (psid):   262.77
                Temperature Drop (°F):    1.17
(COMPRESSOR)
             Suction Temperature (°F):  63.22
          Discharge Temperature (°F):  185.65
             Suction Pressure (psia):  139.35
           Discharge Pressure (psia):  434.61
            Discharge Superheat (°F):   65.36
         Comp Bottom Shell Temp (°F):  128.37
             Mass Flow Rate (lbm/h):   369.70
         Comp Power Consumption (W):   2297.4
            Cond Unit Inlet Temp (°F):   58.63
          Cond Unit Inlet Pres (psia): 140.51
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 08
  FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
           FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.28
  Indoor Dry-Bulb Temperature (°F):    70.03
 Indoor Dew-Point Temperature (°F):    51.06
 Outdoor Dry-Bulb Temperature (°F):    99.66
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.03
  Inlet Dew-Point Temperature (°F):    51.06
    Exit Dry-Bulb Temperature (°F):    51.57
   Exit Dew-Point Temperature (°F):    48.62
       Inlet Relative Humidity (-):    0.510
        Exit Relative Humidity (-):    0.896
    Evaporator Coil Temp Drop (°F):    18.46
             Air Flow Rate (SCFM):   1025.0
         Fan Power Consumption (W):   416.46
(OUTDOOR UNIT)
             Inlet Temperature (°F):    99.66
              Exit Temperature (°F):   114.67
    Condensing Unit Temp Gain (°F):    15.01
         Fan Power Consumption (W):   154.84
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   3380.6
         Sensible Capacity (Btu/h):  20717.9
          Overall Capacity (Btu/h):  24098.4
           Sensible Heat Ratio (-):    0.860
     Overall Power Consumption (W):   2924.7
         NET Cooling EER (Btu/h.W):     8.24
   Evaporator Energy Imbalance (%):     1.93
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    47.72
              Exit Temperature (°F):    56.02
              Inlet Pressure (psia):   154.99
               Exit Pressure (psia):   143.69
               Pressure Drop (psid):    11.30
                Exit Superheat (°F):    11.36
        Exit Sat. Temperature (°F):    44.66
       Evaporator Capacity (Btu/h):  24998.3
(CONDENSER)
             Inlet Temperature (°F):   182.53
              Exit Temperature (°F):   106.02
              Inlet Pressure (psia):   444.48
               Exit Pressure (psia):   442.89
               Pressure Drop (psid):     1.59
               Exit Subcooling (°F):    15.58
       Inlet Sat. Temperature (°F):   122.26
        Condenser Capacity (Btu/h):  34179.5
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   105.18
        Cond Unit Exit Pres (psia):   437.05
     Liq-line Pressure Drop (psid):    11.14
       TXV Upstream Pressure (psia):   425.91
          TXV Pressure Drop (psid):   270.92
              Temperature Drop (°F):     1.27
(COMPRESSOR)
          Suction Temperature (°F):    63.33
        Discharge Temperature (°F):   187.84
           Suction Pressure (psia):   141.69
         Discharge Pressure (psia):   445.33
          Discharge Superheat (°F):    65.64
        Comp Bottom Shell Temp (°F):   130.81
           Mass Flow Rate (lbm/h):   375.22
        Comp Power Consumption (W):   2353.4
         Cond Unit Inlet Temp (°F):    58.85
       Cond Unit Inlet Pres (psia):   142.90
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 09
  FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
           FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.74
  Indoor Dry-Bulb Temperature (°F):    80.31
 Indoor Dew-Point Temperature (°F):    60.09
 Outdoor Dry-Bulb Temperature (°F):    99.75
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.31
  Inlet Dew-Point Temperature (°F):    60.09
    Exit Dry-Bulb Temperature (°F):    61.04
   Exit Dew-Point Temperature (°F):    57.29
       Inlet Relative Humidity (-):    0.502
        Exit Relative Humidity (-):    0.875
    Evaporator Coil Temp Drop (°F):    19.28
             Air Flow Rate (SCFM):   1016.9
         Fan Power Consumption (W):   421.38
(OUTDOOR UNIT)
             Inlet Temperature (°F):    99.75
              Exit Temperature (°F):   116.54
    Condensing Unit Temp Gain (°F):    16.79
         Fan Power Consumption (W):   156.86
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   5069.7
         Sensible Capacity (Btu/h):  21572.8
          Overall Capacity (Btu/h):  26642.5
           Sensible Heat Ratio (-):    0.810
     Overall Power Consumption (W):   2858.3
         NET Cooling EER (Btu/h.W):     9.32
   Evaporator Energy Imbalance (%):     7.21
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):    55.71
              Exit Temperature (°F):    66.39
              Inlet Pressure (psia):   175.88
               Exit Pressure (psia):   163.27
               Pressure Drop (psid):    12.61
                Exit Superheat (°F):    13.97
        Exit Sat. Temperature (°F):    52.42
       Evaporator Capacity (Btu/h):  29167.9
(CONDENSER)
             Inlet Temperature (°F):   175.36
              Exit Temperature (°F):   108.25
              Inlet Pressure (psia):   437.39
               Exit Pressure (psia):   435.25
               Pressure Drop (psid):     2.14
               Exit Subcooling (°F):    10.85
       Inlet Sat. Temperature (°F):   121.00
        Condenser Capacity (Btu/h):  38070.9
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   108.20
        Cond Unit Exit Pres (psia):   427.59
     Liq-line Pressure Drop (psid):    15.53
       TXV Upstream Pressure (psia):   412.06
          TXV Pressure Drop (psid):   236.18
              Temperature Drop (°F):     0.78
(COMPRESSOR)
          Suction Temperature (°F):    71.35
        Discharge Temperature (°F):   179.35
           Suction Pressure (psia):   161.02
         Discharge Pressure (psia):   438.10
          Discharge Superheat (°F):    58.44
        Comp Bottom Shell Temp (°F):   125.32
           Mass Flow Rate (lbm/h):   435.65
        Comp Power Consumption (W):   2280.0
         Cond Unit Inlet Temp (°F):    68.36
       Cond Unit Inlet Pres (psia):   162.17
```

```
        HEAT PUMP FAULT TEST SUMMARY

      INDOOR/OUTDOOR CONDITION #: 09
 FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
          FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.39
  Indoor Dry-Bulb Temperature (°F):     79.72
 Indoor Dew-Point Temperature (°F):     60.69
 Outdoor Dry-Bulb Temperature (°F):     99.72
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.72
  Inlet Dew-Point Temperature (°F):     60.69
    Exit Dry-Bulb Temperature (°F):     60.31
   Exit Dew-Point Temperature (°F):     57.40
       Inlet Relative Humidity (-):     0.523
        Exit Relative Humidity (-):     0.901
    Evaporator Coil Temp Drop (°F):     19.41
              Air Flow Rate (SCFM):    1008.0
         Fan Power Consumption (W):    412.00
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.72
              Exit Temperature (°F):    116.78
    Condensing Unit Temp Gain (°F):     17.06
         Fan Power Consumption (W):    154.91
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    6048.6
         Sensible Capacity (Btu/h):   21541.2
          Overall Capacity (Btu/h):   27589.8
           Sensible Heat Ratio (-):     0.781
     Overall Power Consumption (W):    2901.9
         NET Cooling EER (Btu/h.W):      9.51
    Evaporator Energy Imbalance (%):     4.95
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     55.54
              Exit Temperature (°F):     66.13
              Inlet Pressure (psia):    176.40
               Exit Pressure (psia):    163.49
               Pressure Drop (psid):     12.91
                Exit Superheat (°F):     13.63
          Exit Sat. Temperature (°F):     52.50
       Evaporator Capacity (Btu/h):   29458.5
(CONDENSER)
             Inlet Temperature (°F):    178.03
              Exit Temperature (°F):    106.89
              Inlet Pressure (psia):    447.24
               Exit Pressure (psia):    445.23
               Pressure Drop (psid):      2.01
               Exit Subcooling (°F):     14.41
         Inlet Sat. Temperature (°F):    122.74
        Condenser Capacity (Btu/h):   38523.0
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    106.43
         Cond Unit Exit Pres (psia):    437.52
      Liq-line Pressure Drop (psid):     15.27
        TXV Upstream Pressure (psia):    422.25
           TXV Pressure Drop (psid):    245.84
              Temperature Drop (°F):      0.69
(COMPRESSOR)
          Suction Temperature (°F):     71.21
        Discharge Temperature (°F):    182.07
            Suction Pressure (psia):    161.33
          Discharge Pressure (psia):    447.93
           Discharge Superheat (°F):     59.42
        Comp Bottom Shell Temp (°F):    127.27
            Mass Flow Rate (lbm/h):    434.57
        Comp Power Consumption (W):    2335.0
           Cond Unit Inlet Temp (°F):     68.02
        Cond Unit Inlet Pres (psia):    162.46
```

```
        HEAT PUMP FAULT TEST SUMMARY

      INDOOR/OUTDOOR CONDITION #: 09
 FAULT TYPE: REFRIGERANT OVERCHARGE FAULT
          FAULT LEVEL [%]: 30.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.37
  Indoor Dry-Bulb Temperature (°F):     79.99
 Indoor Dew-Point Temperature (°F):     60.66
 Outdoor Dry-Bulb Temperature (°F):     99.76
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.99
  Inlet Dew-Point Temperature (°F):     60.66
    Exit Dry-Bulb Temperature (°F):     60.28
   Exit Dew-Point Temperature (°F):     57.47
       Inlet Relative Humidity (-):     0.517
        Exit Relative Humidity (-):     0.904
    Evaporator Coil Temp Drop (°F):     19.71
              Air Flow Rate (SCFM):    1007.9
         Fan Power Consumption (W):    412.94
(OUTDOOR UNIT)
             Inlet Temperature (°F):     99.76
              Exit Temperature (°F):    116.84
    Condensing Unit Temp Gain (°F):     17.07
         Fan Power Consumption (W):    155.43
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    5861.8
         Sensible Capacity (Btu/h):   21874.4
          Overall Capacity (Btu/h):   27736.1
           Sensible Heat Ratio (-):     0.789
     Overall Power Consumption (W):    2981.4
         NET Cooling EER (Btu/h.W):      9.30
    Evaporator Energy Imbalance (%):     4.97
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
             Inlet Temperature (°F):     55.73
              Exit Temperature (°F):     66.15
              Inlet Pressure (psia):    176.69
               Exit Pressure (psia):    164.10
               Pressure Drop (psid):     12.59
                Exit Superheat (°F):     13.42
          Exit Sat. Temperature (°F):     52.73
       Evaporator Capacity (Btu/h):   29620.9
(CONDENSER)
             Inlet Temperature (°F):    181.51
              Exit Temperature (°F):    106.62
              Inlet Pressure (psia):    460.50
               Exit Pressure (psia):    458.64
               Pressure Drop (psid):      1.87
               Exit Subcooling (°F):     17.36
         Inlet Sat. Temperature (°F):    125.03
        Condenser Capacity (Btu/h):   38942.4
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    105.86
         Cond Unit Exit Pres (psia):    451.06
      Liq-line Pressure Drop (psid):     15.17
        TXV Upstream Pressure (psia):    435.90
           TXV Pressure Drop (psid):    259.20
              Temperature Drop (°F):      0.74
(COMPRESSOR)
          Suction Temperature (°F):     71.39
        Discharge Temperature (°F):    185.62
            Suction Pressure (psia):    161.97
          Discharge Pressure (psia):    461.19
           Discharge Superheat (°F):     60.67
        Comp Bottom Shell Temp (°F):    129.32
            Mass Flow Rate (lbm/h):    435.25
        Comp Power Consumption (W):    2413.0
           Cond Unit Inlet Temp (°F):     68.19
        Cond Unit Inlet Pres (psia):    163.05
```

D.8 Presence of Non-Condensable Gas Fault Tests

Table D.8. List of raw data for presence of non-condensable gas fault tests

Test condition #	Nominal chamber condition			Fault Type	Fault level (%)
	T_{ID} (°F)	ϕ_{ID} (%)	T_{OD} (°F)		
4	70	50	82	NON	5.0
5	80	50	82	NON	5.0
5	80	50	82	NON	10.0
5	80	50	82	NON	16.0
5	80	50	82	NON	20.0
8	70	50	100	NON	5.0
8	70	50	100	NON	10.0
8	70	50	100	NON	16.0
8	70	50	100	NON	20.0
9	80	50	100	NON	5.0

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 04
         FAULT TYPE: NON-CONDENSABLE GAS FAULT
                   FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
          Barometric Pressure (inHg):    30.65
    Indoor Dry-Bulb Temperature (°F):    70.09
   Indoor Dew-Point Temperature (°F):    50.70
   Outdoor Dry-Bulb Temperature (°F):    81.69
AIR SIDE CONDITIONS
(INDOOR UNIT)
     Inlet Dry-Bulb Temperature (°F):    70.09
    Inlet Dew-Point Temperature (°F):    50.70
      Exit Dry-Bulb Temperature (°F):    50.70
     Exit Dew-Point Temperature (°F):    47.27
         Inlet Relative Humidity (-):    0.502
          Exit Relative Humidity (-):    0.880
      Evaporator Coil Temp Drop (°F):    19.39
               Air Flow Rate (SCFM):    1037.9
           Fan Power Consumption (W):   436.15
(OUTDOOR UNIT)
               Inlet Temperature (°F):   81.69
                Exit Temperature (°F):   96.48
      Condensing Unit Temp Gain (°F):   14.78
           Fan Power Consumption (W):   164.27
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   4601.5
           Sensible Capacity (Btu/h):  22022.8
            Overall Capacity (Btu/h):  26624.4
             Sensible Heat Ratio (-):    0.827
       Overall Power Consumption (W):   2359.8
          NET Cooling EER (Btu/h.W):    11.28
     Evaporator Energy Imbalance (%):     2.08
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):   45.67
                Exit Temperature (°F):   55.45
                Inlet Pressure (psia):  148.70
                 Exit Pressure (psia):  138.81
                 Pressure Drop (psid):    9.89
                  Exit Superheat (°F):   12.84
             Exit Sat. Temperature (°F):  42.60
         Evaporator Capacity (Btu/h):  27633.8
(CONDENSER)
               Inlet Temperature (°F):  148.94
                Exit Temperature (°F):   88.38
                Inlet Pressure (psia):  337.79
                 Exit Pressure (psia):  335.72
                 Pressure Drop (psid):    2.08
                 Exit Subcooling (°F):   10.87
            Inlet Sat. Temperature (°F): 101.48
          Condenser Capacity (Btu/h):  34733.7
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):   88.64
           Cond Unit Exit Pres (psia):  329.77
        Liq-line Pressure Drop (psid):   10.27
          TXV Upstream Pressure (psia):  319.50
             TXV Pressure Drop (psid):  170.79
                 Temperature Drop (°F):    0.88
(COMPRESSOR)
             Suction Temperature (°F):   60.54
           Discharge Temperature (°F):  153.07
              Suction Pressure (psia):  136.69
            Discharge Pressure (psia):  338.63
             Discharge Superheat (°F):   51.67
         Comp Bottom Shell Temp (°F):  110.43
              Mass Flow Rate (lbm/h):  375.41
         Comp Power Consumption (W):   1759.4
             Cond Unit Inlet Temp (°F):   57.74
         Cond Unit Inlet Pres (psia):  137.94
```

```
              HEAT PUMP FAULT TEST SUMMARY

             INDOOR/OUTDOOR CONDITION #: 05
         FAULT TYPE: NON-CONDENSABLE GAS FAULT
                   FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
          Barometric Pressure (inHg):    30.74
    Indoor Dry-Bulb Temperature (°F):    80.01
   Indoor Dew-Point Temperature (°F):    60.50
   Outdoor Dry-Bulb Temperature (°F):    81.80
AIR SIDE CONDITIONS
(INDOOR UNIT)
     Inlet Dry-Bulb Temperature (°F):    80.01
    Inlet Dew-Point Temperature (°F):    60.50
      Exit Dry-Bulb Temperature (°F):    59.22
     Exit Dew-Point Temperature (°F):    56.24
         Inlet Relative Humidity (-):    0.514
          Exit Relative Humidity (-):    0.898
      Evaporator Coil Temp Drop (°F):    20.78
               Air Flow Rate (SCFM):    1018.0
           Fan Power Consumption (W):   433.71
(OUTDOOR UNIT)
               Inlet Temperature (°F):   81.80
                Exit Temperature (°F):   98.73
      Condensing Unit Temp Gain (°F):   16.93
           Fan Power Consumption (W):   164.38
(OVERALL PERFORMANCE)
             Latent Capacity (Btu/h):   7639.1
           Sensible Capacity (Btu/h):  23276.1
            Overall Capacity (Btu/h):  30915.2
             Sensible Heat Ratio (-):    0.753
       Overall Power Consumption (W):   2375.2
          NET Cooling EER (Btu/h.W):    13.02
     Evaporator Energy Imbalance (%):     2.67
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
               Inlet Temperature (°F):   54.04
                Exit Temperature (°F):   65.10
                Inlet Pressure (psia):  169.87
                 Exit Pressure (psia):  159.40
                 Pressure Drop (psid):   10.46
                  Exit Superheat (°F):   14.15
             Exit Sat. Temperature (°F):  50.94
         Evaporator Capacity (Btu/h):  32207.8
(CONDENSER)
               Inlet Temperature (°F):  147.79
                Exit Temperature (°F):   90.00
                Inlet Pressure (psia):  347.48
                 Exit Pressure (psia):  344.91
                 Pressure Drop (psid):    2.57
                 Exit Subcooling (°F):   10.52
            Inlet Sat. Temperature (°F): 103.56
          Condenser Capacity (Btu/h):  39283.5
(LIQUID LINE AND TXV)
             Cond Unit Exit Temp (°F):   90.66
           Cond Unit Exit Pres (psia):  337.44
        Liq-line Pressure Drop (psid):   14.44
          TXV Upstream Pressure (psia):  323.00
             TXV Pressure Drop (psid):  153.13
                 Temperature Drop (°F):    0.46
(COMPRESSOR)
             Suction Temperature (°F):   68.35
           Discharge Temperature (°F):  151.07
              Suction Pressure (psia):  157.15
            Discharge Pressure (psia):  348.29
             Discharge Superheat (°F):   47.60
         Comp Bottom Shell Temp (°F):  110.01
              Mass Flow Rate (lbm/h):  433.53
         Comp Power Consumption (W):   1777.1
             Cond Unit Inlet Temp (°F):   66.77
         Cond Unit Inlet Pres (psia):  158.34
```

```
            HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: NON-CONDENSABLE GAS FAULT
               FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.77
  Indoor Dry-Bulb Temperature (°F):    80.07
 Indoor Dew-Point Temperature (°F):    60.64
 Outdoor Dry-Bulb Temperature (°F):    81.79
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.07
  Inlet Dew-Point Temperature (°F):    60.64
    Exit Dry-Bulb Temperature (°F):    59.33
   Exit Dew-Point Temperature (°F):    56.23
       Inlet Relative Humidity (-):    0.516
        Exit Relative Humidity (-):    0.895
    Evaporator Coil Temp Drop (°F):    20.75
             Air Flow Rate (SCFM):   1020.5
         Fan Power Consumption (W):   431.00
(OUTDOOR UNIT)
            Inlet Temperature (°F):    81.79
             Exit Temperature (°F):    98.63
    Condensing Unit Temp Gain (°F):    16.84
         Fan Power Consumption (W):   163.94
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   7928.9
         Sensible Capacity (Btu/h):  23298.9
          Overall Capacity (Btu/h):  31227.8
           Sensible Heat Ratio (-):    0.746
     Overall Power Consumption (W):   2381.7
         NET Cooling EER (Btu/h.W):    13.11
   Evaporator Energy Imbalance (%):     2.65
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    53.94
             Exit Temperature (°F):    65.41
             Inlet Pressure (psia):   170.56
              Exit Pressure (psia):   159.60
              Pressure Drop (psid):    10.96
               Exit Superheat (°F):    14.39
        Exit Sat. Temperature (°F):    51.02
       Evaporator Capacity (Btu/h):  32520.7
(CONDENSER)
            Inlet Temperature (°F):   147.50
             Exit Temperature (°F):    89.84
             Inlet Pressure (psia):   348.89
              Exit Pressure (psia):   346.42
              Pressure Drop (psid):     2.47
              Exit Subcooling (°F):    11.12
       Inlet Sat. Temperature (°F):   103.86
        Condenser Capacity (Btu/h):  39523.1
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    90.37
         Cond Unit Exit Pres (psia):   338.82
      Liq-line Pressure Drop (psid):    14.54
       TXV Upstream Pressure (psia):   324.28
           TXV Pressure Drop (psid):   153.72
              Temperature Drop (°F):     0.42
(COMPRESSOR)
          Suction Temperature (°F):    68.53
        Discharge Temperature (°F):   150.77
           Suction Pressure (psia):   157.23
         Discharge Pressure (psia):   349.80
          Discharge Superheat (°F):    46.99
       Comp Bottom Shell Temp (°F):   108.61
            Mass Flow Rate (lbm/h):   436.31
       Comp Power Consumption (W):    1786.8
         Cond Unit Inlet Temp (°F):    66.97
       Cond Unit Inlet Pres (psia):   158.46
```

```
            HEAT PUMP FAULT TEST SUMMARY

           INDOOR/OUTDOOR CONDITION #: 05
       FAULT TYPE: NON-CONDENSABLE GAS FAULT
               FAULT LEVEL [%]: 16.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.41
  Indoor Dry-Bulb Temperature (°F):    80.05
 Indoor Dew-Point Temperature (°F):    60.26
 Outdoor Dry-Bulb Temperature (°F):    81.72
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    80.05
  Inlet Dew-Point Temperature (°F):    60.26
    Exit Dry-Bulb Temperature (°F):    59.19
   Exit Dew-Point Temperature (°F):    56.26
       Inlet Relative Humidity (-):    0.509
        Exit Relative Humidity (-):    0.900
    Evaporator Coil Temp Drop (°F):    20.86
             Air Flow Rate (SCFM):   1008.7
         Fan Power Consumption (W):   435.35
(OUTDOOR UNIT)
            Inlet Temperature (°F):    81.72
             Exit Temperature (°F):    98.64
    Condensing Unit Temp Gain (°F):    16.92
         Fan Power Consumption (W):   163.66
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):   7164.5
         Sensible Capacity (Btu/h):  23148.6
          Overall Capacity (Btu/h):  30313.1
           Sensible Heat Ratio (-):    0.764
     Overall Power Consumption (W):   2435.4
         NET Cooling EER (Btu/h.W):    12.45
   Evaporator Energy Imbalance (%):     5.46
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    53.36
             Exit Temperature (°F):    68.28
             Inlet Pressure (psia):   170.42
              Exit Pressure (psia):   159.69
              Pressure Drop (psid):    10.73
               Exit Superheat (°F):    17.23
        Exit Sat. Temperature (°F):    51.05
       Evaporator Capacity (Btu/h):  32523.7
(CONDENSER)
            Inlet Temperature (°F):   153.95
             Exit Temperature (°F):    89.43
             Inlet Pressure (psia):   358.72
              Exit Pressure (psia):   355.35
              Pressure Drop (psid):     3.38
              Exit Subcooling (°F):    13.76
       Inlet Sat. Temperature (°F):   105.92
        Condenser Capacity (Btu/h):  39785.9
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    89.91
         Cond Unit Exit Pres (psia):   349.00
      Liq-line Pressure Drop (psid):    14.13
       TXV Upstream Pressure (psia):   334.87
           TXV Pressure Drop (psid):   164.45
              Temperature Drop (°F):     1.54
(COMPRESSOR)
          Suction Temperature (°F):    71.57
        Discharge Temperature (°F):   157.41
           Suction Pressure (psia):   157.45
         Discharge Pressure (psia):   359.79
          Discharge Superheat (°F):    51.53
       Comp Bottom Shell Temp (°F):   115.08
            Mass Flow Rate (lbm/h):   431.12
       Comp Power Consumption (W):    1836.4
         Cond Unit Inlet Temp (°F):    69.83
       Cond Unit Inlet Pres (psia):   158.63
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 05
   FAULT TYPE: NON-CONDENSABLE GAS FAULT
           FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.39
  Indoor Dry-Bulb Temperature (°F):     79.92
 Indoor Dew-Point Temperature (°F):     60.28
 Outdoor Dry-Bulb Temperature (°F):     81.77
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.92
  Inlet Dew-Point Temperature (°F):     60.28
    Exit Dry-Bulb Temperature (°F):     59.35
   Exit Dew-Point Temperature (°F):     56.22
       Inlet Relative Humidity (-):     0.512
        Exit Relative Humidity (-):     0.894
    Evaporator Coil Temp Drop (°F):     20.57
              Air Flow Rate (SCFM):    1007.2
          Fan Power Consumption (W):   431.75
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.77
               Exit Temperature (°F):   98.57
    Condensing Unit Temp Gain (°F):     16.79
          Fan Power Consumption (W):   162.79
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    7261.9
         Sensible Capacity (Btu/h):   22794.9
          Overall Capacity (Btu/h):   30056.8
           Sensible Heat Ratio (-):     0.758
      Overall Power Consumption (W):   2473.0
        NET Cooling EER (Btu/h.W):      12.15
   Evaporator Energy Imbalance (%):      3.88
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   52.78
               Exit Temperature (°F):   69.41
               Inlet Pressure (psia):  169.29
                Exit Pressure (psia):  158.78
                Pressure Drop (psid):   10.51
                 Exit Superheat (°F):   18.70
          Exit Sat. Temperature (°F):   50.70
       Evaporator Capacity (Btu/h):   31717.7
(CONDENSER)
              Inlet Temperature (°F):  157.55
               Exit Temperature (°F):   89.03
               Inlet Pressure (psia):  365.89
                Exit Pressure (psia):  362.89
                Pressure Drop (psid):    3.00
                Exit Subcooling (°F):   16.42
         Inlet Sat. Temperature (°F):  107.40
        Condenser Capacity (Btu/h):   38933.0
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):   88.78
          Cond Unit Exit Pres (psia):  356.27
      Liq-line Pressure Drop (psid):    14.91
       TXV Upstream Pressure (psia):   341.35
           TXV Pressure Drop (psid):   172.06
                Temperature Drop (°F):   1.67
(COMPRESSOR)
            Suction Temperature (°F):   72.77
          Discharge Temperature (°F):  161.15
             Suction Pressure (psia):  156.56
           Discharge Pressure (psia):  366.83
            Discharge Superheat (°F):   53.82
         Comp Bottom Shell Temp (°F):  117.74
               Mass Flow Rate (lbm/h):  416.21
         Comp Power Consumption (W):   1878.4
           Cond Unit Inlet Temp (°F):   70.90
         Cond Unit Inlet Pres (psia):  157.74
```

```
        HEAT PUMP FAULT TEST SUMMARY

       INDOOR/OUTDOOR CONDITION #: 08
   FAULT TYPE: NON-CONDENSABLE GAS FAULT
           FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.65
  Indoor Dry-Bulb Temperature (°F):     69.98
 Indoor Dew-Point Temperature (°F):     50.61
 Outdoor Dry-Bulb Temperature (°F):     99.94
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     69.98
  Inlet Dew-Point Temperature (°F):     50.61
    Exit Dry-Bulb Temperature (°F):     51.46
   Exit Dew-Point Temperature (°F):     48.19
       Inlet Relative Humidity (-):     0.502
        Exit Relative Humidity (-):     0.885
    Evaporator Coil Temp Drop (°F):     18.53
              Air Flow Rate (SCFM):    1035.5
          Fan Power Consumption (W):   437.65
(OUTDOOR UNIT)
              Inlet Temperature (°F):   99.94
               Exit Temperature (°F):  114.63
    Condensing Unit Temp Gain (°F):     14.70
          Fan Power Consumption (W):   160.95
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    3292.8
         Sensible Capacity (Btu/h):   20998.0
          Overall Capacity (Btu/h):   24290.8
           Sensible Heat Ratio (-):     0.864
      Overall Power Consumption (W):   2836.6
        NET Cooling EER (Btu/h.W):       8.56
   Evaporator Energy Imbalance (%):     -1.92
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   47.16
               Exit Temperature (°F):   56.17
               Inlet Pressure (psia):  154.71
                Exit Pressure (psia):  142.93
                Pressure Drop (psid):   11.78
                 Exit Superheat (°F):   11.83
          Exit Sat. Temperature (°F):   44.34
       Evaporator Capacity (Btu/h):   24261.8
(CONDENSER)
              Inlet Temperature (°F):  177.70
               Exit Temperature (°F):  107.81
               Inlet Pressure (psia):  425.15
                Exit Pressure (psia):  423.33
                Pressure Drop (psid):    1.81
                Exit Subcooling (°F):    9.62
         Inlet Sat. Temperature (°F):  118.80
        Condenser Capacity (Btu/h):   33142.4
(LIQUID LINE AND TXV)
            Cond Unit Exit Temp (°F):  107.55
          Cond Unit Exit Pres (psia):  417.31
      Liq-line Pressure Drop (psid):    11.09
       TXV Upstream Pressure (psia):   406.22
           TXV Pressure Drop (psid):   251.51
                Temperature Drop (°F):   1.30
(COMPRESSOR)
            Suction Temperature (°F):   63.29
          Discharge Temperature (°F):  182.83
             Suction Pressure (psia):  140.92
           Discharge Pressure (psia):  425.90
            Discharge Superheat (°F):   64.11
         Comp Bottom Shell Temp (°F):  127.08
               Mass Flow Rate (lbm/h):  371.39
         Comp Power Consumption (W):   2238.0
           Cond Unit Inlet Temp (°F):   58.96
         Cond Unit Inlet Pres (psia):  142.13
```

```
           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 08
      FAULT TYPE: NON-CONDENSABLE GAS FAULT
              FAULT LEVEL [%]: 10.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.51
  Indoor Dry-Bulb Temperature (°F):     79.50
 Indoor Dew-Point Temperature (°F):     59.89
 Outdoor Dry-Bulb Temperature (°F):     81.82
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     79.50
  Inlet Dew-Point Temperature (°F):     59.89
    Exit Dry-Bulb Temperature (°F):     59.41
   Exit Dew-Point Temperature (°F):     56.59
       Inlet Relative Humidity (-):     0.512
        Exit Relative Humidity (-):     0.904
    Evaporator Coil Temp Drop (°F):     20.09
              Air Flow Rate (SCFM):    1018.2
         Fan Power Consumption (W):    434.36
(OUTDOOR UNIT)
              Inlet Temperature (°F):   81.82
               Exit Temperature (°F):   98.24
    Condensing Unit Temp Gain (°F):     16.42
         Fan Power Consumption (W):    164.45
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    5925.6
         Sensible Capacity (Btu/h):   22512.1
          Overall Capacity (Btu/h):   28437.7
           Sensible Heat Ratio (-):     0.792
     Overall Power Consumption (W):    2500.9
         NET Cooling EER (Btu/h.W):     11.37
   Evaporator Energy Imbalance (%):      7.16
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   51.61
               Exit Temperature (°F):   68.88
               Inlet Pressure (psia):  166.79
                Exit Pressure (psia):  155.87
                Pressure Drop (psid):   10.92
                 Exit Superheat (°F):   19.30
        Exit Sat. Temperature (°F):     49.57
       Evaporator Capacity (Btu/h):   31098.2
(CONDENSER)
              Inlet Temperature (°F):  158.32
               Exit Temperature (°F):   88.79
               Inlet Pressure (psia):  368.68
                Exit Pressure (psia):  366.70
                Pressure Drop (psid):    1.99
               Exit Subcooling (°F):    17.86
       Inlet Sat. Temperature (°F):    107.96
        Condenser Capacity (Btu/h):   38225.9
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):    87.93
         Cond Unit Exit Pres (psia):   359.13
     Liq-line Pressure Drop (psid):     15.13
      TXV Upstream Pressure (psia):    344.00
           TXV Pressure Drop (psid):   177.21
               Temperature Drop (°F):    1.50
(COMPRESSOR)
           Suction Temperature (°F):    72.31
         Discharge Temperature (°F):   162.16
            Suction Pressure (psia):   153.73
          Discharge Pressure (psia):   369.53
           Discharge Superheat (°F):    54.28
        Comp Bottom Shell Temp (°F):   116.43
            Mass Flow Rate (lbm/h):    406.35
       Comp Power Consumption (W):    1902.1
          Cond Unit Inlet Temp (°F):    70.40
        Cond Unit Inlet Pres (psia):   154.98
```

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           HEAT PUMP FAULT TEST SUMMARY

          INDOOR/OUTDOOR CONDITION #: 08
      FAULT TYPE: NON-CONDENSABLE GAS FAULT
              FAULT LEVEL [%]: 16.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):     30.42
  Indoor Dry-Bulb Temperature (°F):     70.02
 Indoor Dew-Point Temperature (°F):     50.26
 Outdoor Dry-Bulb Temperature (°F):     99.69
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):     70.02
  Inlet Dew-Point Temperature (°F):     50.26
    Exit Dry-Bulb Temperature (°F):     51.48
   Exit Dew-Point Temperature (°F):     48.07
       Inlet Relative Humidity (-):     0.495
        Exit Relative Humidity (-):     0.881
    Evaporator Coil Temp Drop (°F):     18.54
              Air Flow Rate (SCFM):    1027.5
         Fan Power Consumption (W):    436.23
(OUTDOOR UNIT)
              Inlet Temperature (°F):   99.69
               Exit Temperature (°F):  114.52
    Condensing Unit Temp Gain (°F):     14.84
         Fan Power Consumption (W):    159.75
(OVERALL PERFORMANCE)
           Latent Capacity (Btu/h):    2948.7
         Sensible Capacity (Btu/h):   20850.8
          Overall Capacity (Btu/h):   23799.5
           Sensible Heat Ratio (-):     0.876
     Overall Power Consumption (W):    2892.1
         NET Cooling EER (Btu/h.W):      8.23
   Evaporator Energy Imbalance (%):     -0.37
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
              Inlet Temperature (°F):   46.80
               Exit Temperature (°F):   56.44
               Inlet Pressure (psia):  156.21
                Exit Pressure (psia):  144.32
                Pressure Drop (psid):   11.90
                 Exit Superheat (°F):   11.53
        Exit Sat. Temperature (°F):     44.92
       Evaporator Capacity (Btu/h):   24146.9
(CONDENSER)
              Inlet Temperature (°F):  180.71
               Exit Temperature (°F):  107.81
               Inlet Pressure (psia):  435.34
                Exit Pressure (psia):  433.36
                Pressure Drop (psid):    1.98
               Exit Subcooling (°F):    11.45
       Inlet Sat. Temperature (°F):    120.64
        Condenser Capacity (Btu/h):   33186.5
(LIQUID LINE AND TXV)
           Cond Unit Exit Temp (°F):   107.58
         Cond Unit Exit Pres (psia):   427.50
     Liq-line Pressure Drop (psid):     11.22
      TXV Upstream Pressure (psia):    416.28
           TXV Pressure Drop (psid):   260.06
               Temperature Drop (°F):    1.23
(COMPRESSOR)
           Suction Temperature (°F):    63.73
         Discharge Temperature (°F):   185.92
            Suction Pressure (psia):   142.26
          Discharge Pressure (psia):   436.15
           Discharge Superheat (°F):    65.35
        Comp Bottom Shell Temp (°F):   129.45
            Mass Flow Rate (lbm/h):    369.72
       Comp Power Consumption (W):    2296.2
          Cond Unit Inlet Temp (°F):    59.21
        Cond Unit Inlet Pres (psia):   143.51
```

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               HEAT PUMP FAULT TEST SUMMARY

              INDOOR/OUTDOOR CONDITION #: 08
          FAULT TYPE: NON-CONDENSABLE GAS FAULT
                  FAULT LEVEL [%]: 20.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.33
  Indoor Dry-Bulb Temperature (°F):    70.21
 Indoor Dew-Point Temperature (°F):    50.81
 Outdoor Dry-Bulb Temperature (°F):    99.68
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    70.21
  Inlet Dew-Point Temperature (°F):    50.81
    Exit Dry-Bulb Temperature (°F):    51.51
   Exit Dew-Point Temperature (°F):    48.42
       Inlet Relative Humidity (-):    0.502
        Exit Relative Humidity (-):    0.891
     Evaporator Coil Temp Drop (°F):   18.70
            Air Flow Rate (SCFM):     1023.5
         Fan Power Consumption (W):   435.92
(OUTDOOR UNIT)
            Inlet Temperature (°F):    99.68
             Exit Temperature (°F):   114.77
     Condensing Unit Temp Gain (°F):   15.09
         Fan Power Consumption (W):   160.08
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):    3268.8
        Sensible Capacity (Btu/h):   20954.3
         Overall Capacity (Btu/h):   24223.1
          Sensible Heat Ratio (-):     0.865
     Overall Power Consumption (W):   2936.0
         NET Cooling EER (Btu/h.W):     8.25
   Evaporator Energy Imbalance (%):     0.34
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    46.80
             Exit Temperature (°F):    57.66
              Inlet Pressure (psia):  158.41
               Exit Pressure (psia):  146.07
               Pressure Drop (psid):   12.34
                Exit Superheat (°F):   12.02
        Exit Sat. Temperature (°F):    45.64
      Evaporator Capacity (Btu/h):   24743.6
(CONDENSER)
            Inlet Temperature (°F):   182.90
             Exit Temperature (°F):   107.46
              Inlet Pressure (psia):  443.51
               Exit Pressure (psia):  441.45
               Pressure Drop (psid):    2.06
               Exit Subcooling (°F):   13.63
       Inlet Sat. Temperature (°F):   122.09
       Condenser Capacity (Btu/h):   33938.0
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   106.82
        Cond Unit Exit Pres (psia):   435.39
      Liq-line Pressure Drop (psid):   11.91
      TXV Upstream Pressure (psia):   423.49
          TXV Pressure Drop (psid):   265.08
             Temperature Drop (°F):     1.59
(COMPRESSOR)
          Suction Temperature (°F):    64.82
        Discharge Temperature (°F):   188.06
            Suction Pressure (psia):  144.01
          Discharge Pressure (psia):  444.38
          Discharge Superheat (°F):    66.03
       Comp Bottom Shell Temp (°F):   130.99
            Mass Flow Rate (lbm/h):   375.25
        Comp Power Consumption (W):   2340.0
         Cond Unit Inlet Temp (°F):    60.20
       Cond Unit Inlet Pres (psia):   145.25
```

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               HEAT PUMP FAULT TEST SUMMARY

              INDOOR/OUTDOOR CONDITION #: 09
          FAULT TYPE: NON-CONDENSABLE GAS FAULT
                  FAULT LEVEL [%]: 5.0
RUNNING CONDITIONS
        Barometric Pressure (inHg):    30.84
  Indoor Dry-Bulb Temperature (°F):    79.97
 Indoor Dew-Point Temperature (°F):    60.51
 Outdoor Dry-Bulb Temperature (°F):    99.77
AIR SIDE CONDITIONS
(INDOOR UNIT)
   Inlet Dry-Bulb Temperature (°F):    79.97
  Inlet Dew-Point Temperature (°F):    60.51
    Exit Dry-Bulb Temperature (°F):    60.55
   Exit Dew-Point Temperature (°F):    57.23
       Inlet Relative Humidity (-):    0.515
        Exit Relative Humidity (-):    0.888
     Evaporator Coil Temp Drop (°F):   19.42
            Air Flow Rate (SCFM):     1019.8
         Fan Power Consumption (W):   430.82
(OUTDOOR UNIT)
            Inlet Temperature (°F):    99.77
             Exit Temperature (°F):   116.41
     Condensing Unit Temp Gain (°F):   16.64
         Fan Power Consumption (W):   160.80
(OVERALL PERFORMANCE)
          Latent Capacity (Btu/h):    5971.4
        Sensible Capacity (Btu/h):   21799.3
         Overall Capacity (Btu/h):   27770.8
          Sensible Heat Ratio (-):     0.785
     Overall Power Consumption (W):   2876.2
         NET Cooling EER (Btu/h.W):     9.66
   Evaporator Energy Imbalance (%):     1.89
REFRIGERANT SIDE CONDITIONS
(EVAPORATOR)
            Inlet Temperature (°F):    55.19
             Exit Temperature (°F):    66.25
              Inlet Pressure (psia):  175.79
               Exit Pressure (psia):  163.10
               Pressure Drop (psid):   12.69
                Exit Superheat (°F):   13.90
        Exit Sat. Temperature (°F):    52.35
      Evaporator Capacity (Btu/h):   28743.5
(CONDENSER)
            Inlet Temperature (°F):   176.38
             Exit Temperature (°F):   108.17
              Inlet Pressure (psia):  438.33
               Exit Pressure (psia):  436.18
               Pressure Drop (psid):    2.15
               Exit Subcooling (°F):   10.87
       Inlet Sat. Temperature (°F):   121.17
       Condenser Capacity (Btu/h):   37719.1
(LIQUID LINE AND TXV)
          Cond Unit Exit Temp (°F):   108.37
        Cond Unit Exit Pres (psia):   428.62
      Liq-line Pressure Drop (psid):   15.29
      TXV Upstream Pressure (psia):   413.32
          TXV Pressure Drop (psid):   237.54
             Temperature Drop (°F):     0.87
(COMPRESSOR)
          Suction Temperature (°F):    71.33
        Discharge Temperature (°F):   180.36
            Suction Pressure (psia):  160.91
          Discharge Pressure (psia):  439.10
          Discharge Superheat (°F):    59.27
       Comp Bottom Shell Temp (°F):   126.67
            Mass Flow Rate (lbm/h):   430.66
        Comp Power Consumption (W):   2284.5
         Cond Unit Inlet Temp (°F):    68.41
       Cond Unit Inlet Pres (psia):   162.05
```